# FIRST

# LESSONS IN PHYSICS.

FOR USE

IN THE UPPER GRADES OF OUR COMMON SCHOOLS.

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"In Nature, all is Motion, Life, and Labor." Lesson xvii.

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# PREFACE.

The conviction that an elementary knowledge of some important instruments, machines and physical phenomena can and should be given in our Common Schools, has induced the author to prepare the present little volume. Its object is the presentation of a number of phenomena, laws, and applications of the same, specially adapted to the perceptive capacities of the pupils of the upper grades.

Inasmuch as the demand of a large amount of time might delay the introduction of physical science into the Common School, the book has been so prepared as to secure good results in the minimum of time ever given any study in our schools, viz.: one lesson a week.

Each of the thirty-nine lessons commences with a fact familiar to the child, or an easy little experiment, which serves as the basis for the development of a natural law. After this law, comes the application man makes of it—such as the barometer, thermometer, pump and hydrostatic press.

Costly apparatus is unnecessary. A pencil, a marble, a piece of board, of India-rubber, of wire; glass tubes, and

other objects of trifling expense, are sufficient, for our purposes even preferable. The steam engine and other complicated machines should be examined when in actual use at the workshop or other places, by the class in company with the teacher, but not until after the preparatory lesson in the school-room.

Like all instruction, instruction in physics should proceed in concentric circles from the near to the remote. The present volume may be considered as the first and smallest of those circles. Its usefulness in the highest grade of our Common Schools has been shown by practical experience; the author has written it, however, with a view of introducing it into the second, and even into the third.

At the end of every lesson, articles in books and popular magazines are pointed out, where the pupil may find interesting reading matter; and where, while thus improving his leisure time, he may collect material for composition exercises in school.

Explanations regarding the practical working and experiments will be given in the *Teacher's Guide*, to be published simultaneously with the present volume.

C. L. HOTZE.

CLEVELAND, O., April 3, 1871.

# Preface to the Third Edition.

The hearty welcome given to the first edition of this work undoubtedly had its reason in the long-felt want of a text-book suitable for the thousands of girls and boys whose school education ends in the common school. Among the many things there learned, there are few things which they remember to greater advantage than the phenomena and daily applications of the laws of gravitation, the pressure of air, the lever, the pump, the steam-engine, and the telegraph. These realities train the observing powers, instill a love for knowledge, form a preventive against habits of superficial reasoning, and thus tend to diminish explosions, conflagrations, and other calamities, many of which are caused by persons ignorant of the powers of nature. The merchant, the laborer, or the manufacturer will do his work the better for having had his senses trained in observing nature's operations, and his mind disciplined by scientific thought. It may safely be stated that this view is held by most educators in this country, and that the time is fast approaching when physical science will no longer be a stranger in our common schools.

And yet there are a few followers of the cramming-system, who would deny the right of nature to a share in the education of the young; who would not teach about the things themselves, but merely their names and forms. These persons consider objective instruction in the lower grades of schools as simply a transient concession to ephemeral demands, although, during the last two centuries, such men as Cowley, Milton, Locke, Rousseau, Pestalozzi, Whewell, and Macaulay have advocated it. In the upper grades they refuse it admission altogether, notwithstanding its introduction there is urgently pressed by the scientific men of all countries, by the entire periodical press, and the most prominent educators of the world.

These few opponents to progress in education are joined by a still smaller class of persons who are not adverse to the introduction of

physical science into the schools, but who fear, lest the appropriation of time—one lesson a week!—might diminish the habitual number of arithmetical examples, geographical names, and grammatical rules, and thereby vitiate the results of the annual examinations. So some people entertain a groundless prejudice against the acquisition of a foreign language, on the plea that the child's English might suffer. Huxley, in his "Answers to Certain Questions by the Schools Inquiry Commission," says: "Physics lie at the foundation of all science; *and if nothing else were taught, it would be a great gain* to have the youth of this country soundly instructed in the laws of the elementary forces—gravitation, heat, light, and so forth." An English Journal, "Nature," says: "*The notion, that when a child has learned to read, write, and cipher, he is educated, must be eradicated. These are at best but means, and are only the instruments by which education is conducted.*" An editorial in the "Scientific American" (January 14, 1871), ends with the following significant words: "*As object teaching is a mere handmaid of science—is of use only to give scientific habits of thought, and to convey a knowledge of scientific facts, and is worthless without science, the pnblic should see that its introduction into our schools be carried on under the advice of scientific experts*, who shall direct what is best to be taught, and advise with the adepts in teaching how such knowledge may best be imparted. As a journal having the interests of science and education at heart, desiring to see science soundly popularized, and the masses made acquainted with its technical value, we make this suggestion, and furthermore ask: Is there any man of scientific attainments in the present Board of Education? Is there any scientific authority upon its general staff?"

Physical science was introduced into the B and C grammar classes of this city last September; the pupils have now been using First Lessons in Physics for several months, and none of their other studies have been curtailed, yet the average of the monthly examinations does not suffer on that account, and, in the opinion of our teachers, it never will. A peculiar feature connected with the use of this book—one which we trust will not be brought forward as an objection—is, that the children ask a great many questions more or less to the point; and that they find no rest until they have received a satisfactory answer, either from the teacher's experiments or their own. The fact is truly surprising, that

the pupils of the C grade (sixth school-year) passed a very fair examination a few days ago, on questions at the end of the book which were not found too easy for the C grade of the High-school (the tenth school-year). This shows what earnestness may accomplish; and we have but begun

It may be well to state that the modern technical sense of a word sometimes conflicts with its preconceived English meaning, or use; and as a book of this kind demands language both youthful and technical, the author may be excused for having given a slightly different dress to not a few of the laws. He has omitted several of the so-called "properties" of matter which are very puzzling to the young; and, for the sake of simplicity, has treated the somewhat magic "impenetrability" of air as elasticity of air. The independent terms, Force, Motion, and Heat, are better understood by young pupils than Expansive Force, Moving Force, and so forth. The text in fine print, as well as pages 83, 84 and 120, must be omitted in a lesson of less than an hour's length. The development of the steam-engine will find favor from those appreciating the historical element in the school. While the lessons in Optics may claim special clearness in treatment, those in Chemical Electricity, being very difficult for young learners, will need forbearance. A two-fluid element was chosen, because it may be seen in actual use at the telegraph office. The questions in fine print serve for reviews and examinations, but not as equivalents for experiments.

Even a brief perusal of the volume will show the author's intention not to cram the pupil with meaningless facts, to be forgotten as rapidly as they are learned. As no special scientific qualification has been required of the teacher who, to-morrow, may be called upon to impart scientific instruction to her class, a text-book in the hand of the pupil seems for the present a necessity. I earnestly hope that my feeble contribution to so great a cause may not be judged by its shortcomings alone, and that the day may soon come when physical science shall form a regular branch of study in the common school.

C. L. H.

CLEVELAND, O., December 1, 1871.

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### —OF PRESSURE.



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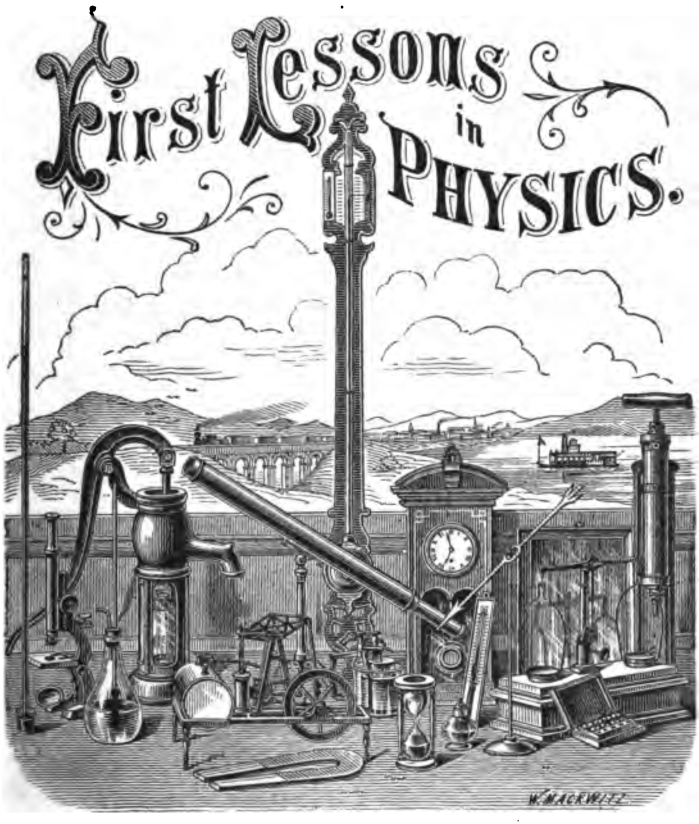


## LESSON I.

### GRAVITY.

1. **Experiment. — A stone in our hand** does not fall, because the hand supports it. But if the hand is withdrawn, the stone falls, and continues to fall, until prevented from falling far-

ther by another obstacle, such as the floor or the ground.

*Familiar Facts.*—Chalk, pencils, paper, pens, and India-rubber, often fall from the desk upon the floor. A stone thrown into a pond sinks to the bottom; a sign-board blown off by the storm falls upon the side-walk; rain, snow, and hailstones, descend to us from the clouds; and large bodies of water, when precipitated from high rocks, form waterfalls. A cat may fall from a house-top; a careless child tumbles down stairs; coals fall through the grate; meal falls through the sieve, and soot through the air. Branches of fruit-trees, hanging full with fruit, break off and fall to the ground; the lily, whose stem is broken, droops its head; the mighty oak in the Western forests, groaning under the blows of the settler's ax, falls with a crash to the ground. Heavy rods are attached to maps and curtains, to draw them down. Clocks are provided with weights, which move slowly in a downward direction; the heavy anchors of vessels plunge into the depths of the ocean.

Having noticed these facts, you naturally inquire, "Why is it that all bodies near the earth have a tendency to approach the earth?" As every State and every town has its laws, so Nature has her laws, which all bodies must obey. All the facts given above may be comprised under

the law: *All bodies fall, if unsupported; they are attracted to the earth.* The force which attracts them is called the *Force of Gravity.*[1]

2. EXPERIMENT. — **This stone is not supported** by my hand (Fig. 1). It is merely suspended. What prevents it from falling? The string. When you draw the stone a little to one side, it moves back again; it wants to stay in one place. And, observe, that the string is kept straight. The string indicates the direction in which the stone would fall, if it were left free to do so. This direction is *vertical.* Who does not know the plumb-line used by carpenters and bricklayers?

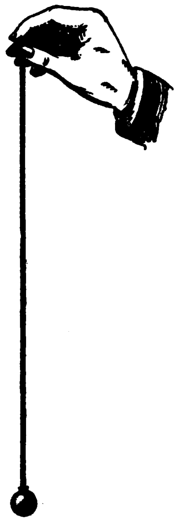

FIG. 1.

*The direction in which a body falls, if moved by the force of gravity alone, is vertical.*

1. That a body, instead of approaching the earth, may sometimes do the opposite, that is, ascend into the air, is due to the influence of other forces. Thus, when a boy leaps a few feet high, he succeeds in overcoming gravity; however, he does so only for a few moments at a time. Birds and winged insects can overcome gravity longer by means of an action peculiar to them, which we call flying. An ordinary fly makes as many as five hundred beats with its wings during a second. But as soon as the influence of other forces ceases, the body must obey the law of gravity. The powerful eagle excels in swiftness the fastest locomotive; yet, when pierced by a deadly shot, he drops like a stone to the hunter's feet.

3. EXPERIMENT.—**Place a large book upon the hand;** the hand will be pressed downward. If a small book be taken, the downward pressure is much less. The small book has not as much weight as the large one.

*Familiar Facts.*—A large stone presses itself into the ground. The weight of a heavy wagon makes deep ruts in a road. When ladies buy silk robes, they lift the article on their hands. Do you know why?

*All bodies press on their support; this pressure is called their weight.*

4. EXPERIMENT.—**A rod balanced** on the edge of the hand has equal weight on each side of the support. The direction of the rod is level, or horizontal. Now, let a crayon be suspended from each end. The rod will still be horizontal, because both crayons have like weight; they are attracted to the earth with the same force on either side. If a number of crayons be suspended from one end of the rod, and a standard of weight, such as ¼, ½ or 1 lb., from the other, we have a crude form of the scale, or balance.

A **balance** is an instrument for weighing. The pieces of iron, brass, or lead, used as standards, are the weights. Instead of the edge of the hand, a metal pivot is used. At each end of the beam a pan is suspended. When a person buys a pound of sugar, why does he see that the beam of the balance is horizontal? Did it ever enter your mind that, when buying a pound of sugar, you actually bought a quantity of

sugar whose force of gravity amounted to a pound? That is, you bought a mass of sugar which is attracted by the earth to the amount of a pound. It matters not to gravity of what kind a substance is. A pound of coffee is as heavy as a pound of lead; a pound of feathers, as a pound of iron.

*Application.* — The common balance — clock weights—hour glasses.

**Read** p. 224 and fig. on *Weight of the Earth* in "Things not Generally Known," by David A. Wells. New York: Appleton & Co.

**Read** chapter on "Weight of the Earth" in Bernstein's Popular Treatise on Natural Science. New York: Chr. Schmidt, 39 Centre st.

**Gravity**, as we have seen, is the force which attracts all bodies to the earth. This force is only a portion of the universal force of attraction between all bodies on the earth as well as in the universe (planets and fixed stars). A pound-weight has very nearly the same weight all over the earth; but if taken to the moon it would have less weight; it would weigh only about 1/6 of a pound there. On the sun, which contains 355,000 times as much matter as our earth, the pound would have the weight of about 28 pounds. Owing to that universal force, the planets revolve around the sun. The force with which the sun and moon attract our earth causes the huge tide-waves on the ocean; while the earth's attraction for the moon causes this planet to revolve around the earth about once every four weeks.

## LESSON II.

### SPECIFIC GRAVITY—FLOATING AND SINKING OF SOLIDS.

5. Experiment.—**Take two ink-wells** of the same size. Fill the one with water, the other with oil, and place them on the pans of a balance. The one containing the water will be found to be depressed; evidently the water has more weight than the same bulk of oil. In common words we say, water is heavier than oil; but we ought to say, that water has greater *specific* weight than oil; that is, a bulk of water has more weight than the same bulk of oil; or, water is *denser* than oil. For is not a pound of water as heavy as a pound of oil?

*Specific Gravity is the weight of a substance compared with the weight of a like bulk of some other substance taken as a standard.*

6. Experiment.—**Now first pour the oil** into a tumbler, and then the water. The latter being the heavier, it settles in the bottom, the oil rising above it. Thus oil floats on water, because it has not as much weight as the same bulk of water.

*Familiar Facts.*—Smoke rises high into the air; balloons ascend into the clouds. Each is lighter than a like bulk of surrounding air.

*Fluids of different specific gravity place themselves in the order of their specific gravity—the heaviest below, the lightest above.*

7. Experiment.—**Drop a stone** into a tumbler filled with water; it sinks. A piece of cork would float. Upon one pan of a balance place a tumbler filled to the brim with water; upon the other place as many weights as are necessary to establish equilibrium. Remove the tumbler and drop a stone into it. The stone will sink and some water will run over. The space now occupied by the stone was before occupied by water, and that quantity of water was borne by the water in the tumbler. Now, if the stone had no greater weight than a like bulk of water, it would likewise be borne by the water. That it has, can easily be shown by placing the tumbler with the stone in it on the balance again; the tumbler will have more weight than it had before.

8. Experiment.—**An empty flask, closed** with a cork, floats on water. Look how little water it displaces. It evidently has less weight than a like bulk of water. It would float even if it contained a few pebbles, while a bottle filled with water sinks.

*A body floats, if it has less weight than an equal bulk of water; it sinks, if it has more.*

*Familiar Facts.*—As the flask, so do vessels float, though they be heavily laden. The body of a man has scarcely more weight than a like bulk of water, and will float on water, provided the chest remains filled with air.

QUESTIONS.—1. Why is it difficult for bathers to walk in water chin-deep?

2. In drawing water from a well, why has the bucket more weight as it emerges from the water?

3. Why may heavy stones be lifted in water, while on dry land they can scarcely be moved?

Persons who can not swim, often lose their lives on falling into the water, because, when they first sink the water closes their mouth and nose, preventing them from inhaling air. Frightened by this, they lose their presence of mind, and, instead of holding their breath, they exhale the air from their lungs. Thus they diminish their volume, and are, of course, more apt to sink. Then they foolishly extend their arms into the air; the head then naturally sinks, and, unless rescued, they are drowned. The danger would have been very slight if these persons, on falling into the water, had first held their breath, spread out their limbs, and then quietly folded their arms over the crown of the head. For, by throwing the head slightly backward, a person is enabled to keep his mouth and nose above water, and thus may save his life. If the waves run high, he must, by all means, hold his breath as long as he is submerged; then no water can enter his mouth.

*Application.*—By means of specific gravity the purity of liquids and the value of substances, such as gold-quartz, can be ascertained.

**Read** *Influence of Oil on Water*, p. 256, in "Things Not Generally Known," by David A. Wells. New York: Appleton & Co.

## LESSON III.

### MAGNETIC ATTRACTION.

9. EXPERIMENT. — **Suspend an iron nail** by a string. The direction of the string will be vertical (Lesson 2). But if we bring a magnet near the nail, the string will incline toward the magnet; the more so, the nearer the magnet is brought to the nail. On approaching it still nearer it will attach itself to the magnet, and, if detached, contrary to gravity, will not fall. This is owing to *Magnetic Attraction.*

Reverse the last experiment. Suspend the magnet at one of its ends, and lay the nail on the table. Holding the nail with one hand so as to keep it steady, the magnet will be seen to move toward the nail and adhere to it in spite of gravity. This shows that *Magnets and unmagnetic iron attract each other.*

10. EXPERIMENT.—**If iron filings be placed** on a piece of paper or glass, they will likewise be attracted by the magnet. The latter need not be in contact with them; it may be placed under the paper, or even under the table. Magnetic attraction, like attraction of gravity, operates also through intervening bodies.

Let the magnet be placed lengthwise in the iron filings and turned round several times. On withdrawing it we find that it is covered at the ends with long threads of the filings, while toward the middle they become shorter, and in the center of the magnet the attraction is so slight that no filings adhere. From this we see that the *power of a magnet resides chiefly at its ends.*

11. EXPERIMENT.—**The ends of a magnet** are called its polls. Attach the magnet at its center to a string, and suspend it from the hand. The magnet will vibrate until it finally takes a certain position, which it keeps. If disturbed, it will again vibrate, and after many vibrations, resume the same position. It will do so anywhere, in the room or out-doors. Upon examining the direction, we find that it is north and south. That end of the magnet which points north is called its *north pole*, that which points south, its *south pole.*

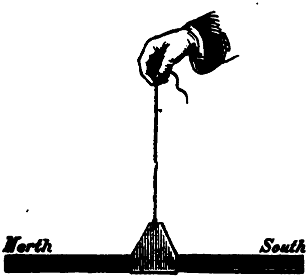

FIG. 2.

*A freely suspended magnet points north with one end; south, with the other.*

12. EXPERIMENT.—**Bring the north pole** of a magnet near the north pole of a magnet freely suspended; it will be repelled. The same is

seen, if the south poles are brought together. The magnets will not come to rest before the north pole of the one has found the south pole of the other.

*Like poles repel each other; unlike poles attract each other.*

*Application*—The most important application of this property of the magnet is the *Magnetic Needle*, or *Compass*, used by surveyors and mariners.

A needle may easily be rendered magnetic by means of a magnet. Lay a needle upon the table and hold its point with the left hand. Taking the magnet with the right, place it with its *north pole* upon the *center* of the needle. Then pass it slowly along the right-hand part of the needle, rubbing the needle in the direction from the center to the eye. When arrived at the eye, the magnet must be raised from the needle and passed through the air back to the center, there to recommence the same operation with the same pole. This process must be repeated about thirty times. After that, the magnet is reversed, taken into the left hand, and, while the right now holds the needle, placed upon the center of the needle. By rubbing the magnet from the middle of the needle to the left end, returning through the air, and repeating this the same number of times as the first process, the needle becomes a perfect magnet. It will attract iron, and be attracted by the same; it will point north and south, if suspended at the middle and if left to move freely.

Magnets have usually the form of a horse-shoe, so that the poles are brought near together; this more than doubles their supporting capacity.

**Read** "*Magnetism,*" in Faraday's "Six Lectures on the Various Forces of Matter." New York: Harper & Brothers.

**Read** "Terrestrial Magnetism," in Harper's Monthly, Vol. 1, p. 651.

## LESSON IV.

### ELECTRIC ATTRACTION.

The ancient Greeks gave amber the name of Electron; they knew that if amber was rubbed it would attract small, light bodies. This attractive power is called *Electricity*.

13. EXPERIMENT.—**Rub a piece of sealing wax**, a bar of sulphur, or a lamp-chimney, with a piece of flannel, and bring it near light bodies, such as tiny bits of paper, wafers, or small feathers. They will adhere to the sealing wax, sulphur or glass, which have become *electric*, and have now the power of attracting light bodies.

14. EXPERIMENT.—**Heat a piece of writing paper** over a stove or lamp. Place it upon a table, rub it several times with a piece of India-rubber, and then bring it quickly near some light bodies; it will attract them. From this we see that *Friction produces Electricity*, and that *electric bodies attract light bodies.*

15. EXPERIMENT.—**If, in a very warm room,** where there are but few persons, and where the atmosphere is perfectly dry, we bring the knuckle near electrified sulphur, glass or paper, we may see a spark pass from the substance to the

hand.[1] At the same time, we also hear a crackling noise, feel a slight stinging in the hand, and smell a peculiar odor near the electrified object.

*Familiar Facts.*—**The fur of a cat** sparkles when rubbed with the hand in cold weather. The sparks are seen best in the dark. If *the electric paper* be held against one's face, a peculiar sensation is felt, as though the face were being covered with a cobweb. The reason of this is, that the fine hair on the face is attracted by the paper and caused to move. *Sparks a foot long* are often seen when there is strong friction between the rubber bands and the wheels of a machine.

But what has become of the electricity that passed from the sulphur, or glass, to the knuckle while emitting a spark? If it had remained there, the knuckle would certainly attract light bodies; but this is not the case. Neither the knuckle nor the hand shows any sign of electricity. It spread

1. As it often depends upon uncontrollable circumstances whether a spark can be obtained by such simple means, the following contrivance has been suggested: "Take a glass tube of ½-inch bore and a little over a foot long. Then take an iron wire, coil it spirally, and insert it into the tube—the windings should be ¼-inch distant from each other, and must rest firmly against the inner surface of the tube. One end of the wire is to protrude from the tube, and a tin ball to be soldered on to the protruding end. The other end of the spiral wire should not extend farther than the middle of the tube, in order that about six inches of the tube may be used as a handle. On rubbing the tube, a spark may be obtained from the tin ball."

all over the body and over the earth, and thus it was sensibly lost. If we bring a key near electrified sulphur or glass, or a tin ball (see foot note p. 21), a spark will likewise be seen passing over to the key; but the electricity which the key receives does not stay there; it passes into the hand, and thence through the body to the ground. This shows that *metals and the human body are good conductors of electricity.* If in place of the hand and the key, we take sealing wax, silk or glass, no spark will be seen, and they will remain electric after the contact. These objects do not conduct electricity. Hence *sealing wax, silk and glass are non-conductors of electricity.* The difference between *conductors* and *non-conductors* of electricity is this: A *conductor* receives, and loses, electricity immediately on all the parts of its surface. A *non-conductor* receives, and loses, electricity only at the point of contact.

16. EXPERIMENT.—Suspend a pith ball,[1] attached

1. "Pith balls may be obtained best in winter from young elder-trees of one year's growth. The stem is split open with a sharp knife, the pith is cut into small pieces, each of which is rolled between the hands into a ball. To suspend the balls, pierce each with a needle carrying a silk or linen thread, make a knot on the opposite side, and then draw the knot tight a little ways into the ball. The linen thread should be very fine. If silk thread is used, care must be taken that it contain no metallic color, as, for example, Prussic Blue, and that no cotton thread be inside, as cotton is a good conductor. The thread to which the little ball is attached is taken from three to five inches long; one with a ball at each end should, of course, have double the length. They may be

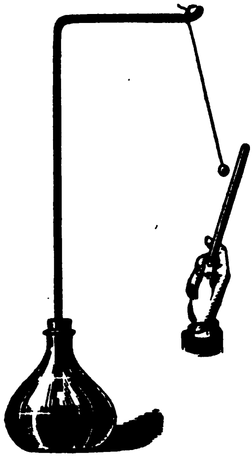

FIG. 3.

to a silk thread, from the hand or some other support (Fig. 3). On presenting it to an electrified bar of sealing wax, it will be seen that the ball is attracted by the sealing wax, that it comes in contact with the same, and that, after it has become electric itself, it is *repelled*. If we then slowly follow it with the sealing wax, it is repelled still farther. The repulsion between the two bodies continues, until the aqueous vapor in the room, or some other good conductor, or the contact of our hand, deprives the ball of its electricity.

17. EXPERIMENT.—**In a similar manner suspend** two pith balls attached to a silk thread. On presenting electrified sealing wax, they become electric themselves by contact with it, and then repel each other. They hang no longer vertically; the attracting and repelling force of electricity may overcome gravity in the same way in which magnetic attraction overcomes gravity.

18. EXPERIMENT—**Repeat the 16th Experiment** with a single pith ball; after it becomes electric,

suspended from a strong wire bent at right angle, which may be inserted in the cork of a bottle, so as to give it firm support."

present it to an electrified glass rod or tube.[1] The ball will be immediately attracted by the electricity of the glass.

19. EXPERIMENT.—**Repeat the 17th Experiment,** and after the two balls are separated by repulsion, present electrified glass to one of them. The glass will attract this ball and impart its electricity to it; after which the ball will be repelled from the glass and at once fly to the other ball.

When the two balls had the same kind of electricity, they *repelled* each other; now that they possess different electricities—the one glass electricity, the other sealing-wax electricity—they *attract* each other.

20. EXPERIMENT.—**Again suspend two pith balls.** Bring electrified sealing wax near the one, electrified glass near the other. The balls will at first be attracted and then repelled, when they will fly toward each other and stay together. This is easily understood if we remember that one ball had glass electricity, and the other seal-

1. "Glass differs greatly with respect to electrical purposes. Some varieties are good conductors of electricity, because they contain metal. Hard glass, and common green bottle glass, if not colored with metal, are non-conductors, and, therefore, well adapted for that purpose. All kinds of glass, however, are *hygroscopic*, that is, they draw moisture from the atmosphere. For this reason thick glass rods are preferable to glass tubes. Before being used, both, tubes and rods, should be slightly heated, and should be rubbed with a warm cloth."

ing wax, or, as it is called, *resinous* electricity. From all this it appears that there are two kinds of electricity—*Vitreous* or *Glass Electricity*, and *Resinous Electricity*. The former is also called *positive* electricity, the latter *negative electricity*.

*Like electricities repel each other; unlike electricities attract each other.* (For a similar phenomenon see the preceding lesson.)

*Historical.*—The sparks obtained by the rubbing of furs, and lightning, with its companion, thunder, must have been observed by the earliest people upon the earth. Although the Greeks, about 600 years before the Christian era, recorded the attracting property of amber, it was not before the beginning of the 17th century, that a book was published by Dr. Gilbert, an Englishman, who mentions many other substances, such as glass and sulphur, as having the same property. This author stated correctly that *magnetism attracted as well as repelled*, but, curiously enough, he added that electricity only attracted.

In 1670, the first electric machine was constructed by Otto Guericke, burgomaster of Magdeburg, the inventor of the air-pump. He also discovered the property of electric repulsion. He excited electricity by means of sulphur (brimstone) exposed to friction.

The distinction between *conductors* and *non-conductors* of electricity was discovered by Mr. Stephen Grey. He wished to electrify a cord suspended by linen threads, but was unsuccessful because the electricity, when entering the cord, at once passed over to the threads. The threads thus were found to be conductors of electricity. Upon the suggestion of a friend he tried silken threads, and as silk is a non-conductor, the experiment then met with the desired result.

Du Fay distinguished between *vitreous* and *resinous* electricity. A number of other scientists afterward improved the electric machine, and by continuous research added largely to the progress of the science. But they were eclipsed by Dr. Franklin who astonished the world by drawing electricity from the clouds.

## LESSON V.

### LIGHTNING.—LIGHTNING RODS.

**A lamp-chimney** yields only a small spark; but the glass disk in an electrical machine, such as is used in High Schools and Colleges, produces a long, zigzag spark, resembling a flash of lightning. It had long been supposed that lightning was an electric phenomenon, but it was not until 1752 that, through the genius of our countryman, Benjamin Franklin, all doubts were removed. Having long been thinking over the subject, he one day saw a boy fly a kite, and the idea at once struck him that he must make one himself and send it into the clouds. Accordingly he stretched a silk handkerchief upon two sticks, in the form of a cross, on the top of which he fastened a pointed iron wire. This he connected with the hempen string holding the kite, and upon the approach of a thunder-storm he went out, accompanied only by his little son. The hempen string was attached below to a key, and the key was insulated by silk string which Franklin held in his hand. The clouds were passing rapidly, but without any apparent effect upon the kite; and the two observers, standing below and watching it with great anxiety, were about to abandon the

undertaking, when suddenly the fibres of the string bristled up, and a crackling noise was heard. Franklin now presented his knuckle to the key, and received an electric spark, which was soon followed by an abundance of sparks as the string became wet with the falling rain.

Franklin's experiment, together with many experiments by scientific men in Europe, demonstrated beyond a doubt, that *all rain clouds are electric.*

*Familiar Facts.*—**When two such clouds** approach each other, their electricities try to unite. In doing so, one of them leaps over the space between them. This passage of electricity through the air produces a great electric spark which we call *Lightning.*

*Familiar Facts.*—**Lightning mostly passes** from one cloud to another. But it may also pass from the clouds to the earth, and from the earth upward to the clouds. It rarely happens that lightning *strikes*—that is, strikes objects on the earth. *Tall* objects made of *good conducting material* are most liable to be struck—tall objects, because they are nearer to the clouds; good conductors, because electricity can get to the ground soonest through them. High houses, tall steeples, trees or chimneys, therefore, offer a good passage to electricity. In its onward course lightning

always prefers the best conductors; thus it passes along the spouting of houses, along water-pipes, stove-pipes and iron pillars. It *melts* metallic objects; it *splits* trees into fragments, and *kills* living beings by destroying the activity of their nerves.

The safest place during a thunder-storm is that part of a room not too near the fire-place, stove, chandelier, gas-pipe or bell-rope. Why is it unsafe to seek shelter under tall trees, or in the entrance of a house with rain pouring down over it? Knowing that lightning always follows the best conductors, Franklin devised a means by which he might direct its course, and invented the *Lightning Rod.* It consists of a metallic rod, with pointed upper ends, which protrudes several feet above the roof, in order that on the approach of a dense cloud the metallic point, and no part of the building, should be struck. The rod conducts the electricity into the ground, where it can do no harm.

As lightning is an electric spark, so is—on a large scale—thunder the crackling noise which accompanies the electric spark.

**Read** "*Thunder and Lightning,*" in "Illustrated Library of Wonders." New York: Scribner & Co.

**Read** "*Lightning and its Effects,*" page 291, in Wells' "Things Not Generally Known."

**Read** "*Thunderstorm,*" in "The Earth and its Wonders." Cincinnati: Hitchcock & Walden.

# LESSON VI.

## COHESION.

*Familiar Facts.*—**In order to cut meat,** to whittle a stick, to sharpen pencils, to split logs, to saw wood or to plane boards, we find it necessary to use instruments, such as a knife, an ax or a saw. We see that the parts of a solid body are not easily separated; evidently they are very close together. They are held together by a force which we call Cohesion. We know that it is difficult to break a piece of iron, because iron has a strong cohesive force; yet a blow with a poker sometimes may break the door of an iron stove. Rolled or hammered iron is much stronger than cast-iron, because, by the process of rolling or hammering, its particles have been brought nearer together, and hence they cohere more firmly. The strength of our tools and building-material depends upon this cohesive force.[1] We can break wood more easily than iron, because it has less cohesive force. Easier yet to break, or separate,

1. If iron be made to pass through fine openings, iron wire is obtained. (What is this property of iron called?) Iron wire of the thickness of a match may support a weight of forty tons. A cable of wires, each wire having one-third of that thickness. may support a weight of ninety tons.—Suspension bridges.

is water, oil, or air. Place the hand in water, now try to place it in wood. This is impossible, for the particles of a solid body cohere more closely than those of a liquid. How easily we can pour water from a pitcher into a tumbler, and oil from a can into a lamp! And that our light-winged songsters can divide the air so swiftly, is owing to the fact that air has even less cohesion than water. We can walk, run, ride or jump in air. To do this in water is more difficult; in molasses, it would be next to impossible.[1]

*To break a body, its force of cohesion must be overcome.*

*Familiar Facts.*—**When a little child breaks his slate,** he tries to put the parts together again, but he quickly perceives that they will not remain together; he must get a new slate. The particles on the surface of the edges can not be brought so near to each other as they were before; that is, they *cohere* no longer. A broken walking-cane, although the broken parts are glued together again, has lost its former strength.

1. When we overcome the force of cohesion of a body, we do so by displacing its parts; we do not in reality penetrate the body. Thus, in driving a nail into a board, the nail merely displaces parts of the board. A body can not occupy the space of another body unless that other body be first removed; that is, no two bodies can occupy the same space at the same time. If an inverted tumbler be placed in water, the water can not fill it, because the air in the tumbler has no means of escape. See Lesson X.

But it is different with a liquid; two parts of water can readily be made to form one mass by pouring them together.

The greater or less resistance which the body offers when being broken, determines the degree of its cohesive force. A solid body has more cohesion among its parts than a liquid. Gaseous bodies have no cohesion at all.

Examples: Ice, water, steam.

The great enemy of cohesion is Heat.

*Familiar Facts.*—**Although solids and liquids cohere,** they contain a great number of holes, which are called *Pores.* They may be of different size in the same body, and they may be visible or not. *The pores of our skin* are so minute that they can not be detected without a magnifying glass. Every square inch of our skin contains about 1,000 pores. Our health depends largely upon their activity.[1]

*Solid and liquid bodies are porous.*

*Application.*—(*a.*) Of Cohesion: Beams and Pillars. Wire; Thread; Rope, &c., &c. (*b.*) Of Porosity: The Sponge; Blotting-Paper.

1. In the year 1661 the Academy of Florence proved that pores exist even in gold. A thin globe of gold was filled with water, and the orifice carefully closed. A violent pressure was then brought to bear upon it, and the result was, that the water was forced through the pores of the gold, and stood like dew upon the outer surface of the globe.

## LESSON VII.

### ADHESION.—CAPILLARY ATTRACTION.

21. EXPERIMENT.—**Cut two leaden bullets** with a pen-knife so as to form two bright surfaces, and let the two faces be pressed against each other until they are in the closest contact; they will be found to adhere firmly to each other.

*Familiar Facts.*—**The same takes place**, if a piece of India-rubber be cut and the two surfaces be pressed together. Dealers in glass-ware know that when mirrors have been placed together with their surfaces, they are often broken in the attempt to separate them. *Between solid bodies, adhesion takes place if the surfaces are highly polished;* that is, if they are so smooth that the parts of one surface closely approach those of the other. If not highly polished, the surfaces will not adhere—as two bricks laid together. Nor will adhesion take place, if thin paper is placed between the two polished surfaces.

As a general thing, bodies which we wish to adhere to one another, are not very smooth. Owing to the unevenness on their surface, many of the parts of one surface are prevented from coming in close contact with those of the other;

in this case there can be no adhesion. What may be done, then, in order to make two rough surfaces adhere? Simply put a liquid body between the two, to fill out the unevenness.

22. EXPERIMENT.—**Put two moistened glass** plates together, and it will require some effort to separate them. The same may be found if two boards are placed together with water between them.[1]

Why does the hand become wet when immersed in water? Why does it remain dry when drawn out from mercury? Because, in the first case, the adhesive force between the water and hand is stronger than the cohesive force of the water; in the other case, the cohesive force of the mercury is stronger than the adhesive force between it and the hand. Thus, when the hand is placed in water, a struggle takes place, as it were, between the adhesive and cohesive force of the water. The hand comes out victorious, for on withdrawing, it carries off a portion of the water.

1. Between paper we put mucilage; between bricks, mortar; between the pieces of a broken dish, cement. Adhesion takes place between the surface of these bodies and the liquid; cohesion between the parts of the liquid. It is thus that the two surfaces of glass, paper, brick and porcelain are made to adhere to each other.

*Adhesion is the attraction between the surfaces of bodies in contact with each other.*

*Application.*—All gilding, painting, whitewashing, cementing, varnishing, gluing, writing, soldering, coating of looking-glasses, plating, &c., &c. Soot adheres to the chimney; dust to the ceiling; chalk, and fresh paint, to one's dress.

23. EXPERIMENT.—**Immerse a clean glass plate** partly in water, some of the water will be seen to rise on both sides of the plate. Evidently the adhesive force between the glass and the water is greater than the cohesive force of the water. Were it not so, the water would not rise. Now immerse another glass plate near the first and not parallel to it (Fig. 4). Water will rise between them, and the form of its surface will be concave. The nearer the glass plates are brought to each other the higher will the water rise between them. This is natural, for the quantity of water between them is in this case very small; and the cohesive force of the water, therefore, easily overcome by the adhesive force. If a glass tube be immersed (see

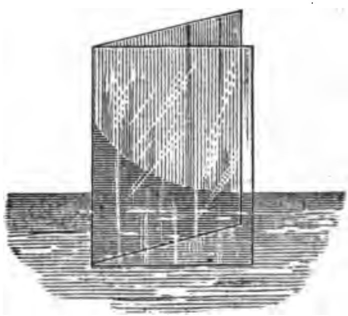

FIG. 4.

Fig. 5) the water will rise still higher, because here is a small quantity of water, surrounded on all sides by glass, and the force of adhesion is, therefore, comparatively of greater effect.[1]

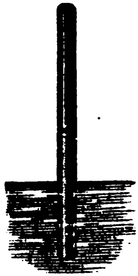

FIG. 5.

Capillary tubes are tubes so small that nothing thicker than a horse-hair can pass through them. When such a tube comes in contact with a liquid whose cohesive force it overcomes, the liquid is compelled to rise in it. The finer the bore of the tube the higher will the liquid rise in it. In a tube 1-100 of an inch in diameter water will rise over five inches.

*Capillary attraction is the result of adhesion operating between solid and liquid bodies.*

*Application.* — Sponge, blotting paper. Eggs and meat may be kept fresh in sand or pulverized charcoal, these two substances containing capillary tubes which absorb any moisture that would otherwise affect the eggs or the meat. Lamp-wicks likewise contain capillary tubes; these support combustion, although there may be but little oil. Grease spots in the floor may be removed by laying earth upon them. Our clothes become wet from the rain. In short, *everything about us is filled with fine capillary tubes.*

1. But the reverse of all these phenomena takes place—that is, water is always depressed about glass surfaces, if these are greased. Grease has no attraction for water; the water, consequently, is left free to obey its cohesive force, and falls below the level of the liquid surrounding the tube.

## LESSON VIII.

### REVIEW.

LESSON I.—

*All bodies are attracted* to the earth. The force which attracts them is called the Force of Gravity.

2. *All bodies fall if unsupported;* if *supported*, they press upon their support; if *suspended*, they pull in the direction in which they would fall if left free to do so.

3. *The direction in which a body falls*, if it is moved by gravity alone, is *vertical.*

4. *The pressure of bodies* upon their support is called Weight.

5. *A pound is a weight*, indicating a certain amount of that pressure taken as a standard.

LESSON II.—

6. *The specific gravity of a substance* is its weight, compared with the weight of a like bulk of some other substance taken as a standard. When we say, mercury has a specific gravity of 13.5, we mean that any bulk of mercury has 13.5 times as much weight as a like bulk of water.

7. *Fluids of different specific gravities*, when brought together, place themselves in the order of their specific gravities, the heaviest below.

8. *A body which is lighter* than a quantity of water of equal bulk, floats on water; one which is heavier, sinks.

LESSON III.—

9. *The attraction between magnets* and iron is called Magnetic Attraction. The attraction which the earth has for magnets, causes the magnetic needle, or any magnet freely suspended, to point north and south.

LESSON IV.

10. *The attraction of electrified bodies* is called Electric Attraction.

LESSON VI.—

11. *The parts of a body are kept together* by their mutual attraction. The attraction between the parts of the same body is called Cohesion.

12. *In order to separate a body*, its cohesion must first be overcome. If it is difficult to break, we call the body *tenacious;* if difficult to penetrate, we call it *hard*.

LESSON VII.—

13. *The attraction between the surfaces* of bodies in contact, is called Adhesion.

14. *The adhesion between solids and liquids* is often called Capillary Attraction.

15. *Gravity*, *Magnetism*, *Electricity*, *Cohesion*, and *Adhesion*, are forces of attraction. The last two are called Molecular Forces, because they bind molecules[1] together.

16. *The first three*—Gravity, Magnetism and Electricity—act through great distances; adhesion and cohesion only at an *insensible* distance.

17. *Instead of magnetic and electric attraction*, we may witness *magnetic and electric Repulsion*, while gravity, cohesion and adhesion, however, exert only attraction.

*Questions.*—What natural force is applied in the balance— the compass—the lightning rod—suspension bridges—blotting paper?

1. "A molecule is the smallest particle of matter into which a body can be divided without losing its identity." Thus, the smallest particles of bread or of salt, which are still bread or salt, respectively, are *molecules* of bread or of salt.

# LESSON IX.

## ELASTICITY.

*Familiar Facts.*—**More than a thousand years ago, long before powder was invented, our ancestors used the cross-bow for the purpose of fighting the enemy as well as for the pleasures of the chase. At present, the cross-bow is used only by certain savage tribes, and as a plaything by our children. If you draw the string of the cross-bow, and then let it go again, the arrow placed before the string flies off with astonishing rapidity. "How is it," may we ask, "that a string can obtain such great force?" If we double a piece of India rubber between two fingers, it straightens again when the pressure is removed. After pressing a steel pen gently against our thumb nail to try its writing qualities, it immediately returns to its former shape. Steel blades and whalebones likewise resume their former shape after having been bent. Steel, ivory, and India-rubber, possess this prop-**

1. Bodies such as lead, cotton, clay, show very little elasticity. Formerly, it was believed that they had none; hence they were called *inelastic;* but even these bodies are not without elasticity; and it may safely be asserted that there are no inelastic bodies. Indeed, were it not that all bodies are more or less elastic, it would be difficult for us to live. Were not the ground, the floor, the walls of our houses, the tables and chairs elastic, every contact with them would hurt us. Were not our paper and pens elastic, how long would it not take us to commit our thoughts to paper! Were not wood elastic, every stroke of wind would blow branches of trees down upon us.

erty in a high degree. Such substances are called *elastic*. Stone, lead, glass and many other bodies possess it to a small extent. Yet glass, when drawn out in fine threads, is so elastic that tissues have been woven from them.

23. EXPERIMENT.—**Take an ivory ball; press** it with your hand upon a slab of marble that has been blackened over a lamp. The ball will show a black spot about as large as a pin's head. Now lay the slab on the floor, stand on the table, and let the ball drop upon the slab from a considerable height. The ball will then have a black spot very much larger than before. Although of a hard substance, the ball is flattened to that extent when it strikes the slab, and in resuming its former shape, it rebounds.

*Familiar Facts.*—**An India-rubber ball** is flattened still more, and therefore rebounds farther. *A soap bubble*, striking against the wall, sometimes rebounds. *Air*, too, is elastic. This may be seen by striking upon a bladder inflated with air. *When powder is ignited*, gases are developed whose elastic force is so great that it overcomes everything before it.

*The parts of an elastic body return to their former position, when the external force which displaces them ceases to act.*

Bodies, such as glass or sugar, that break if the displacing force is beyond the limits of their elas-

ticity, are called *brittle*. Bodies, such as metals, whose parts instead of breaking may assume a different position, are either *malleable* or *ductile*.[1] The malleability of iron may be seen in sheet iron, and in the plates of gun-boats; its ductility, in the telegraph wire.

*Questions.*—When are bodies said to be dense? rare? soft? hard? brittle? malleable? ductile?

*Application of Elasticity*:—1. *To produce motion:* Watch-springs; springs in watch-cases, boxes, and carriage-lanterns; the ballista of the ancients; the cross-bow; locks, and triggers. 2. *To counteract concussion:* Wagon-springs; packing glass-ware in hay or straw; springs in mattresses, sofas, chairs and etui-cases. 3. *To cause close contact or pressure:* Springs in pocket-inkstands; printers' cylinders; some kinds of pen-holders. 4. *For weighing:* Spring-balances

1. Gold is very malleable. Gold leaf is hammered out so thin that it takes 300,000 sheets, placed one upon another, to make the thickness of an inch. Platinum is very ductile. 3,000 feet of platinum wire of a certain thickness were found to weigh only about *one grain*. A single silk-worm thread possesses a thickness equal to that of 140 such fine threads of platinum. Now, as a foot contains 144 lines, and as the tenth part of a line is readily visible to the naked eye, it follows that a single grain of platinum can be drawn out into 4,320,000 parts, each of which is distinctly visible.

# LESSON X.

## ELASTICITY OF AIR.

24. Experiment.—**If we immerse an inverted tumbler** perpendicularly in water, only a very little of the water will enter the tumbler, and, of course, the air in the tumbler is compressed. If the vessel is pressed down still farther, a little more water enters it, but it will never be entirely filled with water, because it contains air. A cork previously placed in the tumbler, will show the position of the water-level inside. (See Fig. 6.) Air maintains its place like every other body, and presses upon bodies. Its pressure is distinctly felt, and if you withdraw the hand which presses the tumbler down, the tumbler will instantly rise. The air in the glass was *compressed*, and tended to expand again, because *air*, like other bodies, *is elastic.*

FIG. 6.

25. Experiment.—**If a glass funnel be immersed** instead of a tumbler, and if inverted with the mouth downward, the upper end being closed with the thumb, the air in the funnel is compressed. As the thumb is removed, however, water rushes into the funnel, forcing out some of the air.

26. Experiment.—**Cement a funnel** into the neck of a bottle and pour water into it. Only a small quantity of water will enter, unless the funnel is placed in the bottle loosely, so that there is a passage for the air. For, as the water is poured into the funnel, it forces the air in the tube of the funnel into the bottle. The air in the bottle being thus greatly compressed, its elastic force resists the downward pressure of the water.

27. Experiment.—**Another beautiful illustration** of the expansive force of air may be obtained by the "Hero's Fountain." Take a cork which fits into a bottle, and perforate it with a round file. The hole should be made so as to admit with difficulty a glass tube, which is now pushed through the cork. The tube should have a very fine opening above. This being done, fill the bottle about half with water and close it with the cork. Then drive the glass tube farther down, until it nearly reaches the bottom of the bottle. The bottle now contains air in its upper part and water in its lower. On blowing more air into the tube, the air will ascend through the water (Lesson II) and collect in the space above. In so doing, the air over the water is *compressed*, and in trying to expand, it forces the water upward through the tube. The inventor of this little apparatus was Hero,

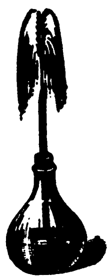

FIG. 7.

a philosopher, who died in Alexandria, before Christ.

*Familiar Facts.*—**The amusing toy**, whose harmless missile darts off with such rapidity, the *pop-gun*, becomes a wonderful object, when we consider the powerful force it serves to illustrate. A piston moves air-tight in the tube of the pop-gun. Let it be at one end of the tube; then insert, air-tight, a stopper into the other end of the tube and commence pushing down the rod; the air inside is now compressed, it has the tendency to expand again; but its force is not great enough, as yet, to drive out the stopper. If the rod is pushed in farther, the air is compressed still more, and the stopper is expelled with a loud report. Another source of amusement is the *blow-pipe*. It consists of a long, smooth wooden tube, into which is fitted a sharp nail, around whose head shreds of cotton are tied. This nail is inserted, and by blowing into the tube at the same end, a great quantity of air is forced in, compressing the air inside; this causes the nail to move forward. On blowing more strongly, the air is compressed more, and its expansive force, therefore, greatly increased. The nail is then expelled from the tube, and its speed will be in proportion to the force with which you have blown into the tube.

The air in a diving-bell is so compressed by the water's trying to enter, that divers often experience great difficulty in breathing.

*Air is an elastic body; the more we compress it, the greater is its expansive force.*

A useful *application* of this property of air is the air chamber, used in connection with pumps. (Comp. Less. 77, p. 78.) The Diving-bell may also be considered an application of this force, because it is the expansive force of the compressed air which prevents the water from entering the bell. (Comp. 24 exp.)

## LESSON XI.

### PRESSURE OF AIR.

28. EXPERIMENT.—**A tumbler filled** with water to the brim, with a piece of paper placed over it, is inverted. (See Fig. 8.) The hand on the paper, after pressing the latter firmly against the tumbler, is removed, but the water does not flow out. How can this be accounted for? Notice that the tumbler contains no air; it is entirely filled with water. The air evidently presses *upward* against the paper. It is this *upward pressure* of the air, which supports the water in the tumbler. Were it not for the paper, the air would force its way into the water, by rushing up along a part of the inner side of the tumbler, leaving the water to fall down on the opposite part.

FIG. 8.

29. EXPERIMENT.—**Immerse a tumbler, horizontally,** into a bowl of water, and press it down gradually. It will fill with water, and afterward be entirely below the surface of the liquid. Now turn it to the vertical position, and without, however, raising its mouth above the surface, lift it as high as possible. The whole tumbler is still filled with water, and will remain filled, although

the water in two communicating vessels ought to have the same height (Lesson XVIII). The tumbler contains no air, while a large amount of air is over the remaining water, pressing *downward* upon the water. It is this *downward pressure* of air which supports the column of water in the tumbler.

30. Experiment.—**Let a vessel be filled** with water; then take a narrow glass tube, open at both ends, and immerse it perpendicularly in the vessel. The tube will partly fill with water; if taken out, the water will flow through the tube and fall, because attracted to the earth. Place the tube again in the water, but so that no air remains in it, and take it out again, keeping the upper opening closed with the thumb. No water will flow from the tube, because air presses against the lower opening and thus supports the column of water in the tube. On removing the thumb the water will flow out, because, in that case, the air presses as strongly above as it does below; the water, consequently, obeys the force of gravity and falls. Holding the glass tube more and more

FIG. 9.

obliquely, until it is in a horizontal position the water will still remain in the tube.

This shows that *air presses not only upward, downward, and laterally, but in all directions.*

*Familiar Facts.*—**From an open faucet** in a full barrel with its bung-hole closed, the liquid does not flow, because the air presses against the opening in the faucet. *To draw vinegar*, or any other liquid from a barrel, plunge a long tube into the liquid; close the upper end with the thumb and withdraw the tube. The liquid in the tube will not flow out (why not?) as long as the thumb closes the upper end. *Oil-cans* must be opened on the top in order to obtain a ready flow

*Application.*—The Barometer (see next lesson). Pneumatic Railway.

Give an example of each of the four applications of Elasticity (Lesson IX).

Read "Impenetrability," p. 3, in Pepper's "The Boy's Playbook of Science." Routledge & Sons, London.

## LESSON XII.

### THE BAROMETER.

**The instrument before you is a Barometer.** It consists of a glass tube with its *upper end closed*, and its *lower end open* (terminating in an open bulb). This end of the tube may be straight, or bent in a curve. The frame is not an essential part of the instrument. Inside the glass tube and bulb is mercury. The mercury does not extend quite up to the closed end; there is a vacant space. Let us examine this space by placing the barometer cautiously in a horizontal position. The mercury will rise to the highest point of the tube. No air could have been in the vacant space; if there had been any, it would not have allowed the liquid to penetrate so far (Lesson X). Let the instrument be put slowly into a vertical position again. The vacant place over the mercury contains no air; it is called a *vacuum*.

Raise the window, and set the barometer in the open air. Our atmosphere is a great many miles in height. The column of air above the bulb presses upon the mercury; for air presses in all directions (Lesson XI). The cause of the mercury's standing so high in the open air is the *pressure of air*. The mercury may be in a leather bag,

enclosed in a wooden or metallic case. The pressure of air, like magnetic attraction and attraction of gravity, is strong enough to act through intervening substances.

Since the pressure of air is so great as to support a column of mercury about 29 inches high, it is evident that the amount of this pressure is equal to the weight of the column. When the atmospheric pressure decreases, the mercury in the tube falls (why?); when it increases, the mercury in the tube rises (why?). Hence *the Barometer is used for measuring the pressure of air.*

Take the barometer back into the room. You will notice that the mercury stands as high as it did in the open air; yet the column of air from the ceiling down, which presses on the bulb, is much shorter. The air out-doors is pressed upon by the layers of air above it; it is *compressed*, consequently it tends to expand (Lesson X). Now, were the air in the room less compressed, the outer air would rush in, until the air in-doors and that out-doors would be equally compressed. Thus both masses of air exert like pressure; *the pressure of the air out-doors is the same as that of the air in the room;* and we can measure it with the barometer in the room or out of the room.

**The height of the column of Mercury** in the barometer **is not always** the same; it varies as the mercury rises or falls. **This shows**

that the atmospheric pressure constantly varies. The reason of this variation is intimately connected with the temperature of our atmosphere. If we always had the same temperature on our planet, the atmospheric pressure (at the same elevation above the ocean's level) would be the same all over the earth. But let any portion of a column of atmospheric air become warmer than its surrounding parts, then its specific gravity (Less. II.) is diminished; it rises, as warm air always does, and passes away to other regions of the atmosphere. Now, the pressure of this column of air has been diminished because the density (Less. II.) of the column is less than before; and, accordingly, the mercury in the barometer *falls*. When any portion of a column of air becomes cooler it becomes denser, and its pressure is increased; the mercury in the barometer then *rises*.

**Winds** that are hot, and therefore light, make our atmosphere less dense, and thus cause the barometer to fall. If, as is usually the case, they are charged with moisture, they bring us rain. Colder winds, however, will make our atmosphere denser, and thus cause the barometer to rise.

**Violent disturbances** of the atmosphere, such as storms, cause the mercury to fall suddenly. At present, by means of the electric telegraph, we can anticipate these atmospheric disturbances, and guard against losses to shipping.

**Hence the use of the barometer** as a weather prophet. But as our weather depends, also, upon other circumstances, the prophecies of the barometer are not very reliable.

The average amount of pressure of air at a temperature of 60 degr. F. is 15 pounds to the square inch. Supposing the surface of an adult to be about 2,000 square inches, the pressure of air continually exerted upon him is about 30,000 pounds.

## LESSON XIII.

### REVIEW.

LESSON IX.—

1. *Bodies tend to resume* their former shape after their parts have been displaced. This tendency is called ELASTICITY.

2. If the displacing force is WITHIN the limit of their elasticity, bodies resume their former shape.

3. If BEYOND, bodies change their former shape.

4. On changing their former shape, bodies may retain their cohesion, and are then said to be either MALLEABLE or DUCTILE; or they may lose it, and are then said to be BRITTLE.

LESSON X.—

5. *Air is an elastic body;* and the more we compress it, the greater is its expansive force.

LESSON XI.—

6. The air about us is constantly pressed upon by the higher strata of air; therefore, it tends to éxpand continually; and, being a fluid, it exerts a constant pressure in all directions.

LESSON XII.—

7. An empty space which contains no air is called a VACUUM.

8. The pressure of the air is measured by means of an instrument called a *Barometer*.

9. When the air of our atmosphere becomes less dense, its pressure is diminished. The mercury in the barometer then falls.

10. When the air of our atmosphere becomes denser, its pressure is increased. The mercury in the barometer then rises.

What force of nature is illustrated by the watch-spring? by gold leaf? by iron wire? by the diving-bell? pop-gun? barometer?

## LESSON XIV.

### INERTIA.

31. Experiment.—**Place a piece of chalk** upon a book, and move the book quickly sideways. The chalk drops to the floor without participating in the motion of the book, because the book is withdrawn from under it.

*Familiar Facts.*—**A coin laid** upon a card on the mouth of a bottle, drops into the bottle if the card is snapped off quickly. It falls, because its support, the card, has been removed from under it. *Persons in a horse-car* are thrown backward if it starts suddenly. These, and numerous other facts, attest that *a body at rest remains at rest until it is set in motion by some force.*

32. Experiment.—**The motion given to the book**, and to the card, was so sudden that there was not sufficient time for it to be communicated to the chalk and coin. Hence it was that these two bodies did not participate in the motion, but dropped, simply because they were left unsupported (Lesson I). Now move the book and the card slowly; the two objects upon them will participate in the motion, and not fall. This shows that for *a body to be set in motion, time is necessary.*

*Familiar Facts.*—**A person running** down hill, a railroad train in motion, can not stop suddenly. Take up your book with the chalk on it, move the book until it strikes against the wall; the chalk will continue to move after the book has ceased moving. So do persons in a car which stops suddenly. A bell continues to ring for a time after it has been pulled.

*A boat* moves on a little if the action of the oars has just ceased. *After stirring the coffee* it will revolve in the cup, although the spoon has been removed. Do you recollect how, when *sleigh-riding* last winter, you came flying down hill on your sleigh, and immediately went up the opposite hill a short distance? *A rabbit* can not run as fast as a hound; but if pursued by the hound, he may, by suddenly changing his course to the right or left, gain considerable advantage over the hound, who, not being prepared for the change, must first overcome his inertia before he can turn. From this we see that *a body once in motion, remains in motion until stopped by some force or resistance. To stop the motion of a body, time is necessary.*

*Familiar Facts.*—**If a moving body** meet with resistance so sudden as not to have sufficient time to stop, the consequences may be terrible. They are terrible to the body moving, if it **can not overcome** the resistance. A rider, galloping, whose horse stops suddenly, flies over the horse's head, and is violently thrown to the ground. A frightful disaster is caused when, in its dashing speed, the locomotive of a train is

suddenly arrested by an obstacle on the track. A boy who in running strikes his feet against a stone, falls with his face to the ground; for the upper part of his body continues moving after his feet have been stopped. For the same reason it is dangerous to leap from a train when it is in motion.

If the body moving can overcome the resistance, the consequences will be borne by the resisting body mainly. A stone thrown breaks through a window. An arrow plunges deep into the side of a horse; and a rifle ball whizzing through the air pierces the person against whom it strikes.

Inertia may be said to be *the indifference of matter as to motion or rest.*

*Application.*—Fly-wheels. The switching-off of trains without a locomotive.

The story goes, that once there was a prince of one of the South Sea Islands who, when he first saw himself in a looking-glass, ran round the glass to see who was standing behind it. So we all would like to know the cause of everything. The cause of Inertia lies clearly before us, when we consider that it is the most natural thing for a body to lie perfectly still as long as it is undisturbed; and, also, that it is quite natural for a body, if once set in motion, to move on forever, if there is no force acting on it so as to disturb that motion. Thus a bullet in a rifle would remain there forever if not acted upon by any disturbing force; the cause of this state of rest is commonly called the Inertia of the ball, and in former times people thought that the ball possessed a special "property" of Inertia. Now, let the rifle be fired off; the ball will shoot forth, and there is no reason why it should not fly on without stopping, like the earth or the moon, provided there be no disturbing force.

## LESSON XV.

### THE INCLINED PLANE.

33. Experiment.—**A ball lying on a book** upon a table will not fall as long as the book lies in a horizontal position. But let the book be raised on one side, and the ball rolls down. It rolls down the faster the higher the book is raised. The ball presses with its whole weight upon the book; but when the book is raised a little on one side the ball presses less, and begins to fall. The higher we raise the book the less will the ball press upon the book, and the more rapidly will it descend. The surface of the book, when raised on one side, is an inclined plane.

*Familiar Facts.*—A **wagon** descending a steep hill need not be drawn by the horses; it is checked rather, in order to prevent it from rolling down too rapidly. When ascending a hill, the horses have a more difficult task than on a level road. It is tiresome for us to ascend *steep stairs.* In loading wagons the *skid* is used. It saves much labor, if it is not placed too steep. If the wagon is very high, the skid must be quite long. The steeper an inclined plane, the greater the velocity of a *body descending on it; and the greater the force required to ascend it.*

34. EXPERIMENT.—**Let an inclined, plane be formed** by a board. (See Fig. 10.) Now it makes a great difference whether the ball is rolled down from the middle, or from the top of the inclined board. Try both. The result will be that the ball, when rolling down from the top, acquires a greater velocity. *A body increases in velocity as the space increases through which it descends.*

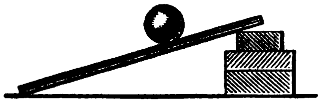

FIG. 10.

35. EXPERIMENT.—**Before the lower end of a grooved board** place a ball. Then let another ball be rolled down the inclined plane, so that it strikes the first ball. Mark the place to which the latter moves, and put it in its former position again. Repeat the experiment, having the upper

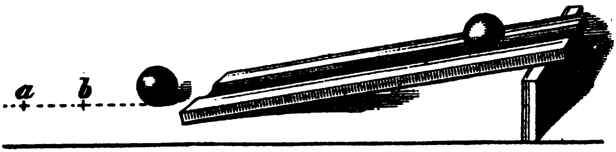


FIG. 11.

end of the board raised a little higher; that is, having the inclined plane a little steeper (Fig. 11). The ball rolling down will then cause the first ball to move farther, perhaps to *a*, and will strike it with greater force. This is owing to the greater steepness of the plane. We have seen that the velocity of a body increases with the inclination of the plane. The last experiment shows that

*the greater the velocity of a body the greater its striking force.*

*Familiar Facts*.—**A bullet thrown** with the hand inflicts less harm than one fired from a gun. *A boy running slowly* against a tree scarcely feels the shock; while by running against it quickly, he might be seriously injured. *We throw a marble* in the air and catch it again without being hurt, but we should experience pain, if the marble were thrown up very high. *Hailstones may strike* with force sufficient to break glass, and to destroy standing grain. *A boy jumps* easily from a fence, but would scarcely dare to jump from the top of a house.

The descent of bodies on the inclined plane shows that they are not supported by it with their whole weight; if they were, they would not descend. To say they are not wholly supported means: An inclined plane overcomes a portion of the weight of bodies upon it. Hence its

*Application*—1. *To overcome weight:* A road winding up a hill. A skid; an obliquely-placed plank; wedges and axes.

2. *To exert strong pressure:* Wedges used in oil-wells, sugar-mills, &c., to press out the juice.

3. *To overcome cohesion.* Our knives, axes, hatchets, scissors, needles, nails, swords, bayonets, saws, files, chisels, planes, plows, &c., &c.

## LESSON XVI.

### THE LEVER.

36. Experiment.—**Balance a rod** horizontally on a slate, supported between two heavy books. The rod is in a state of equilibrium, because on each side of the point of support there is an equal amount of matter. Now, place the rod in such a manner that on one side of the support it shall be twice as long as on the other. The longer arm will descend, because it contains more matter. Let us repeat this slowly. Observe, that in lifting the end of the long arm with the hand, it moves through a greater space than is passed through by the end of the short arm. The lengths of the two arms of the lever are in the ratio of 1 to 2; and the space passed through by the end of the long arm is twice as great as that passed through by the other. Notice, also, that the ends describe these unequal spaces in the same length of time; therefore, *the end of the long arm of a lever has greater velocity than the end of the short arm.*

But it was stated before (Less. XV), that, owing to their great velocity, hailstones, although small bodies, could acquire great power. So will any small weight or object, if it be given great velocity. Apply this to the present case:

37. Experiment.—**Place a heavy weight** on the short arm of a lever. The greater the length of the other arm, the smaller may be the weight upon it requisite to lift the large weight on the short arm. The weight or pressure to be applied to the long arm for that purpose is called the Power. Thus the small power, with the great velocity of the long arm, counterbalances the large weight with the small velocity of the short arm. *A stiff bar made to turn on one point is a lever.*

*The greater the length of one arm of a lever, the less power needs be applied to that arm to lift the load on the other arm.*

*Question.*—What power is needed in a lever to counterbalance the load on the short arm? The amount of power depends, evidently, upon the length of the long arm. If, as in the above case, it has twice the length of the short arm, the power needed to lift and counterbalance the load is *one-half the weight* of the load. Thus, if a burden of 100 pounds is to be lifted by means of a lever whose long arm has twice the length of the short arm, a power of 50 pounds is required; if four times, a power of one-fourth, or 25 pounds. To find the power necessary to lift a load by means of a lever, *divide the product of the load into its distance from the point of support* by *the distance from the point of support to the place where the*

*power is to be applied.* The quotent = the power required.

The important points in a lever: 1. The point of support, or Fulcrum. 2. The load (or weight) to be lifted. 3. The power applied.

In the lever illustrated above, as well as in the applications given below, the order of these three points is: Load—Fulcrum—Power. Levers arranged in this order are called Levers of the First Class.

*Application.*—The Steelyard; Crowbars; Pump-handles; children teetering; scissors and shears.

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If, in order to lift a load, a laborer supports his crowbar on a stone upon the ground, and enters the short arm of the lever thus formed under the weight, his lever is one of the first class; why? But if he does not use the stone; if he simply rests his crowbar with one end on the ground, so that the load comes to lie between him and the fulcrum (the ground), then the order of his lever is: Fulcrum—Load—Power; and this constitutes a Lever of the Second Class.

*Application.—The nut-cracker;* where its limbs are riveted together, is the Fulcrum; the nut represents the load (in this case the load, or resistance, is to be crushed, not lifted); the power is where the hands are applied. We have here two levers combined. The *chopping-knife* is a lever

of the same class. Where the knife is fastened is the Fulcrum. The object to be cut is the Load; the Power is at the handle (in this case, too, the resistance is not a load to be lifted, but cohesion to be overcome).—Lemon-squeezers; Cork-squeezers; the Wheel-barrow;[1] the oar of a boat.[2]

The great progress of our age does not lie so much in the introduction of new forces of nature, of which there are but a few, but in the ingenious *application* of those few forces, and in their skillful combination into *machines*. One of the offices of machines is to communicate the effect of a force to bodies which otherwise could not be acted upon by that force. Thus, without the locomotive, the expansive force of steam could not communicate its effect upon a train of cars.

The Lever is the simplest of all machines; and probably, also, the most ancient. By means of a very long arm, it becomes a most powerful instrument. It is told of Archimedes, a Syracusan philosopher (about 250 years before Christ), that he offered to move the earth itself, if the king would give him a place to stand on.

**Read** on *Levers*, and *The Art of Walking*, in "Things Not Generally Known."

1. The Fulcrum is where the wheel rests on the ground.

2. The Fulcrum is where the oar rests in the water; the Load is the boat.

## LESSON XVII.

### THE PENDULUM.

38. EXPERIMENT.—(*a.*) The string by which a stone is suspended has a vertical direction (Less. I). If the stone is drawn a little to one side, the direction of the string will be slanting. On letting the stone go now, it will begin to move. Since all bodies are drawn to the earth (Less. I), it will approach the earth as near as possible. When nearest the earth, it has again the vertical direction. But the weight does not stop there; its inertia (Less. XIV) carries it onward, being held by the string it does not fall to the ground; it ascends, until gravity finally stops it. Gravity not only stops it, but also pulls it down again. Noticing its downward course more closely, we see that it descends with increasing velocity. Inertia causes it again to pass by the lowest point of its path; it ascends on the other side, stops an instant of time, and is then forced back again by gravity. Thus it swings back and forth for a certain time. Each *swinging in one direction* is called a *vibration.* The vibrations grow shorter, and observation shows us that, finally, they cease altogether.

If, while the pendulum is vibrating, we beat time, it will be found that the same length of time is necessary for the shorter vibrations toward the

close of the experiment as for the earlier longer ones. Thus if the pendulum at first made sixty vibrations a minute, it will continue to make the same number during the same time, although it afterward passes through shorter arcs.

*The vibration of the same pendulum, whether its space is quite short or not, takes place in the same length of time.*

39. EXPERIMENT.—(*b.*) **Cut off three-fourths** of the string. The pendulum is now shorter than it was before; it has only one-fourth the former length. After it is set to vibrating, count the number of its vibrations during a minute; the number will be greater than that of the former pendulum. The reason of this is easily seen, if we suspend the shorter and longer pendulum, both, from the same point. The shorter one descends on a shorter, but steeper, incline than the other, and, therefore, takes less time to descend. This shows that *a short pendulum vibrates more quickly than a long one.*[1]

1. A pendulum which is four times as long as another will need twice as much time to perform one vibration; that is, it will vibrate twice as slowly as the other. Let one pendulum be *nine* times as long as the other, it will need *three* times as much time (it will vibrate three times as slowly); or, it will vibrate *once* while the other vibrates *three* times. Hence the times of vibrations of pendulums are to each other as the square roots of their lengths. Thus, if one pendulum has a length of 4, and another the length of 36, the former will vibrate faster than the latter; the square roots being 2 and 6, the latter will require three times as much time as the other to perform one vibration—that is, if it vibrates once every *three* seconds, the former will vibrate once every *one* second; or, the longer pendulum will vibrate *once* in the same length of time that the shorter one vibrates *three* times.

**The principal application of the pendulum** is its use for the regulation of clocks. A clock is required to keep good time. From the preceding, it is evident that a pendulum, by its vibrations, whether it moves fast or slowly, gives us equal portions of time. But a pendulum will cease vibrating after a short time; what, then, must be done to meet this difficulty? Everybody knows that the pendulum stops when the clock has "run down;" that is, when the weight has descended so far that it can descend no farther. The downward tendency of the weight, then, is sufficient to meet that difficulty; for while the pendulum alone would very soon cease vibrating, the descent of the weight lasts at least 24 hours. (What is meant by winding up a clock?) But the weight, after commencing to fall, increases in speed (Lesson XV), and as the cord from which it is sus-

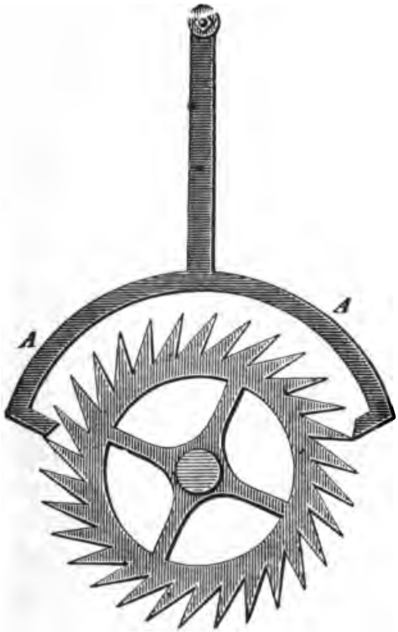

FIG. 12.

pended, passes round an axle which causes the hands to move, the accelerated velocity would cause the hands to move faster and faster. To obviate this, the axle is connected with a wheel of saw-shaped teeth (Fig. 12), which revolves with it, and above which swings a curved hook, *A. A.*, called an *escapement*, whose two teeth work alternately in the saw-shaped teeth of the wheel. At every vibration of the pendulum, one of these two teeth stops the revolution of the wheel, and thus interrupts the descent of the weight. Now, since the pendulum vibrates in equal portions of time, *the weight descends through equal spaces in equal times.* And since the weight descends through equal spaces in equal times, it turns the axle, the work, and the hands with uniform velocity. Hence clocks are *moved* by the descent of the weights, and *regulated* by the vibrations of the pendulum. (See Fig. 13.)

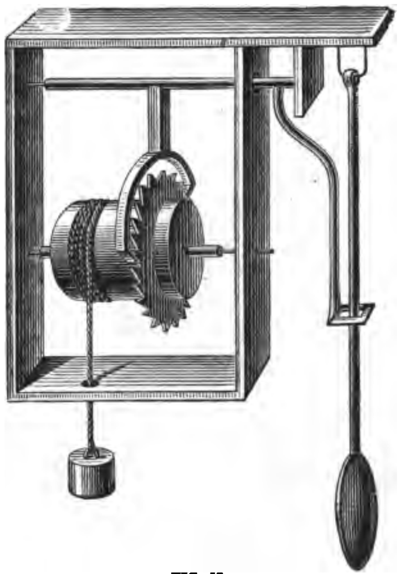

FIG. 13.

## LESSON XVIII.

### COMMUNICATING VESSELS—HYDRAULIC PRESS.

40. EXPERIMENT.—**Fit a piece of thin board** into a tumbler, so that it forms a partition dividing the inside of the tumbler into two spaces. The board should not touch the bottom of the glass, but be a little above it. Now pour water into the tumbler, and there will be two horizontal surfaces of water, each having the same height. Remove the board, and in place of it immerse a wide glass tube. The two surfaces of water will again be of the same height.

*Familiar Facts.*—The same may be seen in two glass tubes of unequal width (Fig. 14) which are cemented into a base made of tin, and connected with each other by means of a tin tube (*a*). Also in a teapot. The tea rises as high in the spout as in the body of the pot, and if the body were higher than the spout the tea would flow from the spout. Hence, in pouring out tea, we lift the pot and lower the spout

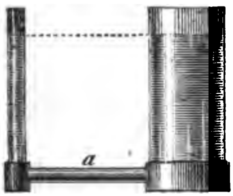

FIG. 14.

41. EXPERIMENT.—**Take a tube** made of glass or tin and bend it so that one limb be very short, perhaps, only one-twentieth as long as the other,

and let the opening of the short limb be drawn out fine (Fig. 15). Then pour water into the long tube, holding the short one closed with the finger. On removing the finger, water will jet forth. Thus we have a fountain on a small scale. If the short tube were tall enough, the water would rise until it stood at a level with the water in the other tube. There being no more tube, however, the water rises in a jet, but not to that level, because there is friction, and because the returning drops depress the rising jet.


FIG. 15.

*Familiar Facts.*—Cisterns, offices, dwelling-houses and factories are supplied with water from large elevated reservoirs.

*Vessels connected with each other, so that a liquid can pass freely from one into the other, are called Communicating Vessels.*

Why may water pipes under ground be said to be communicating tubes?

42. EXPERIMENT.—**Take a cylindrical tin vessel** (about five inches high), with a neck, *B*, perfectly cylindrical (Fig. 16), into which a cork can be fitted tightly, and with small holes in the sides of the vessel as well as in the upper (tapering) part. These openings are carefully closed with beeswax, the vessel filled with water to the very

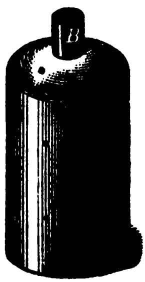

FIG. 16.

edge of *B*, and the cork set on the neck. If the cork is then driven in by a sudden blow with the hand, the water jets forth from all the openings simultaneously. This will not take place, if the vessel be filled with fine sand. The pressure which we gave to the water in the neck was communicated to the larger body of water in the vessel. The effect of that pressure was great, much greater than the original pressure upon the liquid in the neck; it was as many times as great as the surface of tho water in the neck is contained number of times in the cross-surface of the large body of water.

*The force of a pressure brought to bear upon a small portion of a liquid, is transmitted equally (or undiminished) to all parts of the liquid (in all directions).*

Supposing, now, the bottom of the tin vessel had merely been telescoped in the vessel. The pressure given to the water in B, would evidently have forced the bottom out; and the bottom would then have exerted a pressure upon any resisting object in its way.

*Application.*—Advantage has been taken of this in a machine called the "Hydraulic Press," invented in 1796 (Fig. 17). By means of a lever (of the second kind) a pressure is exerted upon the water in the narrow tube, *A*. This pressure is communicated to the water in the wide tube, *c*,

forcing the movable cylinder, *B*, to ascend. Bales of cotton, or any other object to be compressed, lying on the plate, and prevented from yielding by the fixed plate, *P*, are thus compressed with

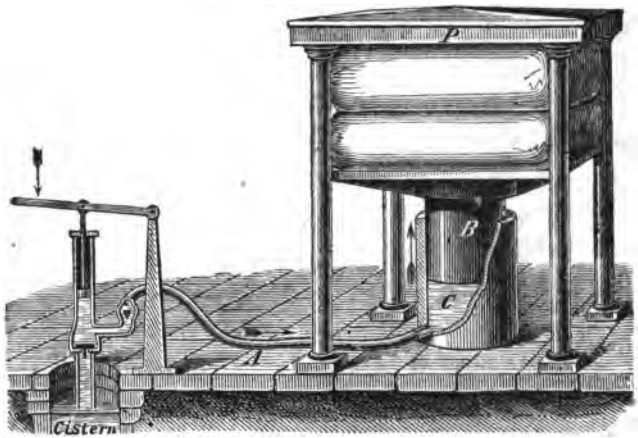

FIG. 17.

enormous force. For if the surface of the water in the cylinder be 100 times that of the water in the narrow tube, and if the pressure applied to the liquid in the tube amount only to 50 pounds, the pressure exerted upon the bale of cotton will amount to 5,000 pounds. But since the power applied by the hand may be increased tenfold with the advantage gained by a longer lever, the amount of pressure may easily be raised to 50,000 pounds. It can be farther increased by steam-pressure so that the force of pressure may amount to over a million pounds.

## LESSON XIX.

### BREATHING.—THE BELLOWS.

43. EXPERIMENT.—**If a glass tube** be placed with one end in water, we can cause the water to rise in the tube by sucking it up with the mouth. This is the reason for it: We draw the air which is in the tube, into the mouth; a vacuum (Lesson XIII) is thus created, and the pressure of the external air upon the water forces water into the tube.

*Familiar Facts.*—**Instead of water** we may draw up air alone; this is done in breathing. We enlarge our lungs and the cavity in our chest (Lesson II, p. 16); by this, the air in the chest is rarefied, and the external air, by the pressure of the layers of air above it, forced to rush into the chest. This process is called Inhalation. During the process of Exhalation we contract the chest, and the air must rush out. *If we immerse a pail* in a pond, and fill it with water, the moment the pail is drawn out again, the water rushes in and occupies the space where the pail was before. In the same way.

*Air rushes into a vacuum, or into any space containing rarefied air.*

A very useful *application* of the pressure of air is the Bellows, an instrument for blowing fire. It consists of a space enclosed by two boards opposite each other, which are united around the edges by a wide strip of leather. In front, this space opens in a narrow tube. In one of the boards is a hole closed by a valve. A valve is a lid over an opening which *admits* a fluid into a space, but *prevents its return.* When the bellows is drawn out, the air inside is rarefied. The external air now seeks to rush in, but it finds no other way than through the valve; this it opens and instantly fills the extended bellows. When the bellows is drawn in, the air inside is compressed, and its expansive, or elastic, force (Lesson X) being greatly increased, it presses against the inner sides of the bellows, and, in doing so, closes the valve. There being no other egress, the air passes through the tube in front into the fire.

On the same principle you may explain Drinking and Smoking.

## REVIEW.

LESSON XV.—

1. The steeper an inclined plane, the greater the velocity of bodies descending on it; and the greater the force required to ascend it.

2. A body increases in velocity as the space increases through which it descends.

3. The greater the velocity of a body, the greater its striking force.

LESSON XVI.—

4. A lever is an inflexible bar made to turn about a fixed point.

5 When moving, the end of the long arm (where the power is applied) has greater velocity than the end of the short arm where the load is attached.

6. The greater the length of the long arm of the lever, the greater becomes its velocity; and, consequently, the less power needs be applied to lift the load.

7. To find the power required to lift a load by means of a lever, divide *the product of the load into its distance from the point of support* by *the distance between the point of support and the place where the power is to be applied*. The quotient is the Power.

## LESSON XX.

### COMMON PUMP.

44. EXPERIMENT.—**Instead of immersing the end of a glass tube, as we did in the preceding lesson, let us dip a syringe into water. On drawing up the *piston*, by means of the *piston-rod*, the liquid is seen to rise in the syringe. This is explained by the law given in the preceding lesson, for the piston being air-tight, it leaves, as it rises, a vacuum below it, which is eagerly filled by the water. But what causes the water to rise? The answer is: The pressure of air on the surrounding water.**

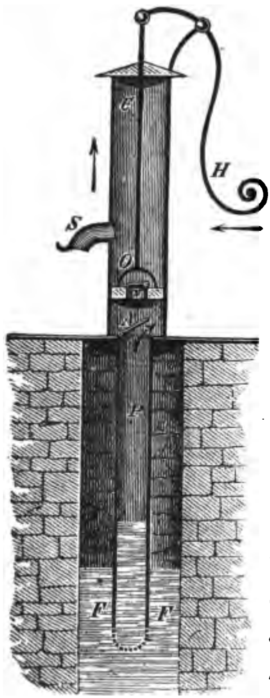

FIG. 18.

*Application.*—**Our pumps. They act on the same principle. When we look at a pump (Fig. 18), the first thing that strikes our eye is the *cylinder*, or *barrel*, *C*, the *spout*, *S*, and the *lever*, or *handle*, *H*. The lower part of the barrel, *P*, is called the**

*suction-pipe;* it is submersed in the water perpendicularly. Inside of the barrel works a piston *O*, which fits air-tight, and can be moved up and down by means of the piston rod to which it is attached. It is pierced with a hole, and the hole is covered with a valve, *v*, which moves upward. The piston-rod is connected at the top with the lever *H*.

When the handle of the pump is drawn out, and has arrived at its highest point, the piston is at its lowest, near the water. If, then, the handle is moved to the left (See Fig. 18), the piston is *raised;* the valve *v* is now closed, because the air above it presses down upon it, and because a partial vacuum has been created below the piston.

We must now turn our attention to another valve, *A*, which is situated between the piston and the surface of the water in the reservoir (in a manner such that the piston, when at its lowest, rests upon it), and which, also, opens upward. When the piston *rises*, this valve is opened, because the air below it—that is, the air between it and the water—expands in order to fill the vacuum caused by the withdrawal of the piston (Less. XIX, p. 71). The air ascends into the space between the lower valve and the piston, and, accordingly, is now rarefied air But the air below that valve is likewise rarefied, and as such (Less. XIX) it has lost a large portion of its expansive

force, and does not press upon the water in *P* as much as the air over the water outside of the suction-pipe, at *F F*. As a consequence of this, the water within *P* is forced to ascend. Then the piston is *lowered*. The valve *A* now closes of its own weight; a portion of air escapes through valve *v*. On raising the piston-rod the second time, more air is withdrawn from the suction-pipe; water commences rushing up, and enters through valve *A*. On lowering the piston again, it descends into the water, and from this moment all the air below the piston is expelled. Some water is now above the piston, and the lower valve again falls of its own weight. Henceforth, whenever the piston *descends*, a large quantity of water passes through the piston-valve *v*; whenever it *rises*, that quantity of water remains on top of the piston-valve. Afterward, at every rise of the piston, the water above it flows out through the spout.

The great principle of the pump is the fact, that the *pressure of air upon a body of water, forces the water to rush up into a vacuum that has been formed above the water in a tube communicating with that body of water.*

Read "*Theory of Pump*," p. 267, in "Things not Generally Known."

## LESSON XXI.

### FORCING PUMP.—FIRE-ENGINE.

**A common pump** will not raise water higher than about 32 feet. The reason of this is, the air over the water can not exert a greater pressure. In order to elevate it to a greater height, the *Forc-*

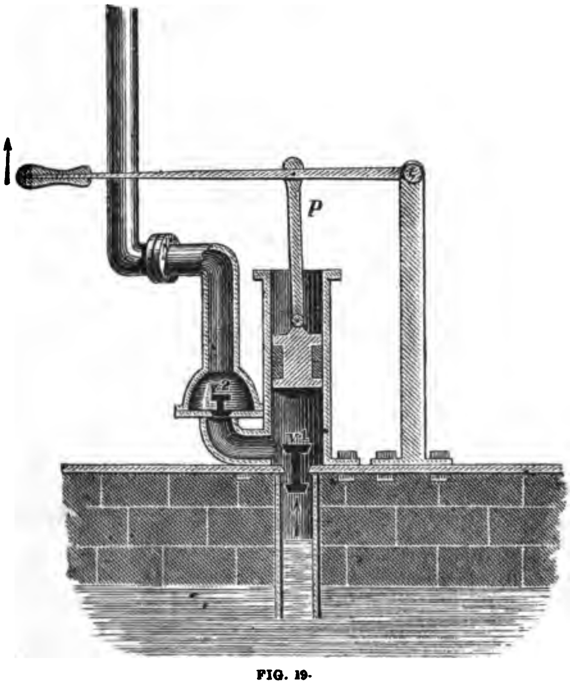


FIG. 19.

*ing Pump* is used (Fig. 19). It is constructed on

the same principle as the Common Pump; it differs from the latter in the following three points: 1. The piston of the Forcing Pump is *not pierced.* 2. In place of the spout there is a tube at the lower part of the barrel, which leads to the place where the water is to be carried. 3. That tube contains a valve, $v^2$, which opens outwardly.

When the piston $P$ is *raised* this valve is closed; thus the air below the piston becomes rarefied, and water is forced through the lower valve $v^1$, the same as in the common pump. When the piston *descends*, the lower valve is closed on account of its own weight; the water above the valve $v^1$ is then forced through valve $v^2$ into the tube, from which it can not flow back. (Why not?)

### The Fire-Engine

Consists of a *Heron's Fountain* (Lesson X) and of *two Forcing Pumps* to pump water into it. Both pumps stand in a large box filled with water. Two iron levers (called *brakes*) $L$ and $L'$, work the iron piston-rods $P$ and $P'$. A wide cylinder, $N$, stands between the two pumps. It contains water, and a metallic tube which nearly reaches to the bottom and is open at the top. This cylinder acts like a "Hero's Fountain," but in the Fire-Engine, and in other pumps, it is called *Air-chamber.* The tubes of the Forcing Pump enter the air-chamber; each has a valve opening outwardly.

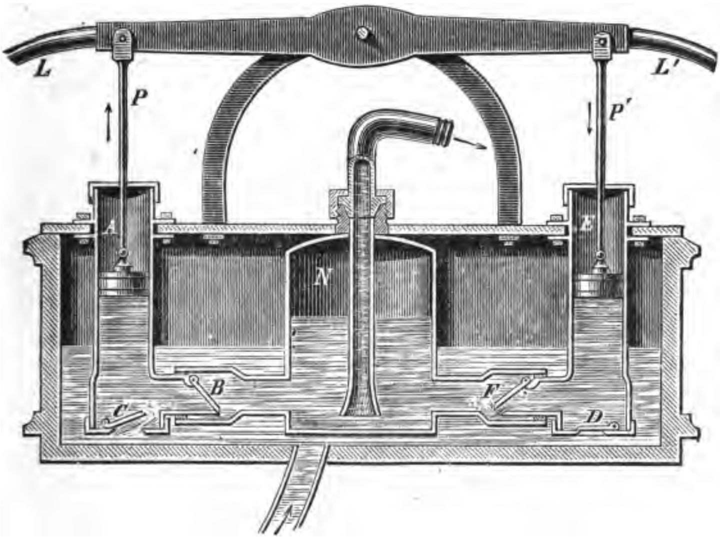


FIG. 20.

When *A*, *one of the pistons*, *rises*, the valve of tube *B* is closed by the pressure, which the air over the water in the air-chamber exerts. Water, at the same time, enters from the box through the lower valve *C* into the barrel of the pump. Why? When the piston *E descends*, the lower valve *D* closes of its own weight, and water is forced into the air-chamber through the valve of the tube *F*. After continued pumping, the water in the air-chamber has risen so high that it has concentrated and compressed the air into a much smaller space. But from Lesson X we see that the more we compress air, the greater its expansive force. Hence it is evident that the jet

of water sent forth from the metallic tube is sent forth by the expansive force of the compressed air in the air-chamber. There being two pumps, the jet is continuous.

Give the difference between the Common Pump and the Forcing Pump.

Also, between a Hero's Fountain and the Air-Chamber of a Fire-Engine.

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**The Common Pump and Barometer Compared.**

Four points in common:

1. Both have a *tube* or *cylinder*.

2. Both have a *vacuum*.

3. In both the liquids rise in consequence of *the pressure of air*.

4. In both, the liquids can not rise higher than the *capacity* of that pressure permits.

Seven points of difference:

1. The *Barometer* has a *glass* tube; *pumps* usually have iron cylinders.

2. The *barometer-tube* is *closed* above the vacuum; while in *pumps* there is a *valve* above the vacuum.

3. The vacuum in the *pump* can never be made as *perfect* as that in the *barometer*.

4. In the *pump*, the vacuum must first be *produced;* in the *barometer*, the vacuum, once established, *remains.*

5. Tho liquid in the *barometer* is always *mercury;* in the *pump* it may be water, oil, vinegar, &c., &c.

6. In the *barometer* neither spout nor lever is required.

7. *No graduated scale* is attached to the *pump.*

8. The liquid column in the barometer usually stands no higher than 30 inches. The liquid column in the pump stands higher than that in the barometer as many times as its specific gravity is smaller than that of mercury. Let the specific gravity of water be one-thirteenth that of mercury; then will a common pump raise a column of water $13 \times 30 = 390$ inch. $= 32\frac{1}{2}$ feet high; however, it never does so in reality, for it is impossible to obtain a perfect vacuum in a pump.

## LESSON XXII.

### REVIEW.

LESSON XVII.—

1. The vibration of a pendulum, whether its space be quite short or not, takes place in the same length of time.
2. A short pendulum vibrates more quickly—makes a greater number of vibrations in the same length of time—than a longer one.
3. In Clocks the motory force is the force of Gravity; in Watches (and in clocks without weights), the motory force is the force of Elasticity.
4. In Clocks the motion is regulated by the Pendulum; in Watches by the Balance-spring.

LESSON XVIII.—

5. Vessels connected with each other, so that a liquid can pass freely from one into the other, are called Communicating Vessels.
6. The force of pressure upon a small portion of any liquid is transmitted equally and undiminished to all the parts of the liquid in all directions.

LESSON XIX—

7. Air rushes into a vacuum, or into any space containing rarefied air.

LESSON XX.—

8. If there is a Fluid between a vacuum and the air, the pressure of air will force the Fluid into the Vacuum. Thus water or mercury rushes into a vacuum formed over a part of its surface, because the pressure of air upon the remaining portion of its surface forces both to do so. (Pumps and Barometer.)

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9. A stone on a support, a weight suspended by a cord, are at rest. They may remain at rest during thousands of years. The force of gravity in them is also at rest. But as soon as the support is withdrawn, or the cord lengthened but the hundreth part of an inch, they begin to move. Then the force of gravity in them may be said to *do work*. That work is called *Motion*.

10. An elastic spring may be compressed, and may remain so for thousands of years. During this time the force of elasticity in it does no work. But withdraw the pressure, and the spring commences moving. *Its motion is the work done by the Force of Elasticity.*

11. *Motion is a manifestation of the work done by a Force, and is always accompanied by a change of place.*

12. *a.* A body on an incline (Fig. 10) will not fall;
*b.* A pendulum (Fig. 13) will not vibrate;
*c.* The long arm of a lever will not move;

*d*. The water in the wide tube of a communicating vessel (if by means of a stop-cock shut-off from the narrow tube) will not flow into the narrow tube (Fig. 14);

*e*. The air outside the bellows will not enter;

*f*. The air over the cistern of a pump will not force the water up (Figs. 18 and 19),

—So long as the force of gravity (in *e* and *f* the force of elasticity) does no work. But from the moment that the rope at the top of the incline, to which the body is fastened, is cut; from the moment that the pendulum-weight be drawn to one side; that the long arm of the lever be provided with additional weight; that the stop-cock in the communicating-tube be opened; that the bellows be extended; that the piston of the pump be moved; —From that moment *Work is done and Motion produced.*

13. The effect of the Force of Gravity is *Pull.* It *pulls* all bodies to the earth. The effect of the Force of Elasticity is *Push* (pressure). These effects disappear when work is being done by the forces; *the forces are then converted into Motion.*

14. The motion of masses is produced by the work which their forces perform. The motions of the human body are work which its forces perform. When its forces cease to labor, Death takes place. *In nature all is Motion, Life and Labor.*

## LESSON XXIII.

### SOUND.

*Familiar Facts.*—When an electric spark leaps over, its passage is followed by a crackling noise, and the passage of lightning through air is followed by thunder. The blow of a whip in the air is also accompanied by a crackling noise; and a pencil, when it falls upon the table, produces a sound which we hear. So does a stone thrown into the water, a book dropped upon the floor, or the hand rapping at the door. Now, if the whip had not moved through the air, nor the pencil upon the table, nor the stone into the water, nor the book on the floor, nor the hand against the door, no sound would have been produced.

*Sound is caused by the motion of a body* (or *mass*).

45. EXPERIMENT.—Insert the Blade of a knife between the horizontal joints on the side of a desk, or table; take the free end of the handle, press it downward as far as convenient, and then let go: a noise will be heard, and the knife will be seen to move up and down very fast until it comes to rest. This is a swinging, vibratory motion, similar to that of the pendulum of a clock.

46. EXPERIMENT.—Let a few drops of water fall into a tumbler filled with water. After first striking the surface, each drop will rise and then

fall again. This vibratory motion is communicated to the remaining water. The water shows it in the circular elevations (rings) round the point of contact. Thus the motion of the knife, as well as that of the water, is a vibratory one.

*Familiar Facts.*—**A vibratory motion** may be heard and felt, when a door is slammed or a gun fired off. A body is first set to vibrate, then it communicates its own vibrations to the air around it, and the air in turn transmits its vibrations to

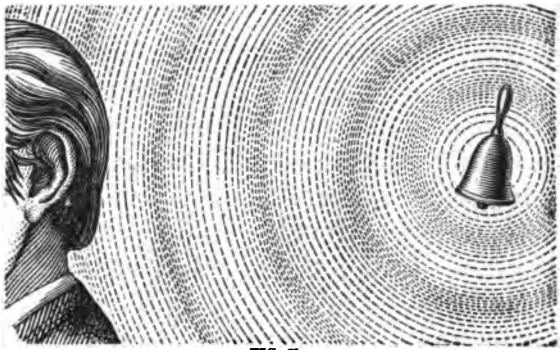

FIG. 21.

the ear. In water, the vibrations are rings; in air, hollow spheres of compressed air, alternating with hollow spheres of rarefied air. No sound is heard if the vibrations are too faint, or too far off to reach the ear; or if one is deaf.

*Familiar Facts.*—**That the sounding-board** of a piano vibrates while the instrument is being played, may be seen if a pin or other small body be placed on it. Blowing into a pipe sets the air

vibrating. In windy weather the church-bells of a city may be heard farther off than usual, at a place which lies in the direction of the wind; while at a place nearer by, but in an opposite direction, they may not be heard at all.

*Sound is caused by the vibratory motion of a body.*

If a cannon is fired off at a distance of about 1100 feet, the flash is seen instantaneously, but the report will be heard a second later. At twice that distance, the report will be heard two seconds later. From the time which elapses between the flash of a gun on a vessel in distress, and the hearing of the report on the shore, the distance of the vessel may be found. Thus, if ten seconds have elapsed, the vessel is about 11,000 feet, a little over two miles, distant. The distance of a thunderstorm may be ascertained in a like manner, by counting the seconds that elapse between the lightning and the thunder following it.

*Sound moves at the rate of about 1100 feet a second.*

*Question.*—1 What causes the noise when a piece of paper is torn? 2. What, when a piece of wood is broken? 3. What, when a whip is cracked?

**Read** "*Wonders of Acoustics,*" in Illustrated Library of Wonders.
**Read** "*The Ear,*" in "Human Body"—Illust. Library of Wonders.
**Read** "*Sound and Echoes,*" p. 268, in Things not Generally Known.

## LESSON XXIV.

### EVAPORATION—FOG—CLOUDS—RAIN—SNOW HAIL—DEW—FROST.

**Water** is one of the most necessary elements in human life. By the Hindoos and other pagan nations, it was revered as a Deity; and the masses of bleached bones lying around the few wells in the desert, show that during great heat the want of water may be death to the traveling caravans.

*Familiar Facts.*—**Moisture** on a slate or on a piece of paper will disappear very soon. Water in a tumbler, exposed to the air, constantly diminishes, until finally none is left. The water in streets, cisterns, ponds, and rivers gradually disappears. When water thus passes off into the air, we say *it evaporates.* Evaporation takes place only at the surface of liquids.

*By evaporation water is changed into aqueous vapor* (the aeriform state of water).

*Familiar Facts.*—**In summer** our breath is invisible; not so in winter, because it cools off immediately after leaving the mouth. In warm weather the vapors rising from rivers, swamps and lakes, are invisible. There may be a great quantity of vapor in the atmosphere, and yet the

vapor not be seen. When the air near the earth is cool, the vapor becomes visible, and then we call it Fog. *Aqueous vapor* (warm, moist air) *coming in contact with cool air, forms Fog.*

The vapor may not be perceived below, but become visible higher up in the atmosphere. This takes place especially when the warm, moist winds (south or southwest winds) come in contact with colder (north or northeast) winds. The vapor then forms *clouds.*

*Fog is clouds near the earth. Clouds are fog in the upper regions of the air.*

*Familiar Facts* —**A piece of chalk,** a piece of earth, a lump of coal, drop quickly; but dust, soot and finely powdered chalk, descend very slowly. The minute water-bubbles of which clouds and fog are composed, may float in the air for a length of time. Being filled with air, their specific gravity permits them to do so. Remember that soap-bubbles may do the same. But when aqueous vapor comes in contact with cold air, its bubbles collapse. Then they form drops and descend as *rain.* On their passage through the air, these drops, small at first, increase in size, because they meet with more aqueous vapor in the air, which condenses upon them. The higher up the clouds, the greater the raindrops. (Why?) *Rain is condensed aqueous vapor.*

In winter, the aqueous vapor in the atmosphere, instead of condensing, freezes and forms minute crystals. These increase in size on their passage through the air, because more of the frozen vapor settles upon them, and reach us as *snow-flakes. Snow is frozen aqueous vapor.*

On stormy summer-days, stones of ice sometimes fall from dense clouds, having an opaque kernel and a transparent rind. They may be disastrous to green-houses and to the crops They are called *Hail-stones.* But it is not known why, in summer, such cold can be produced as to freeze water, for *Hail is, perhaps, frozen rain.*

*Familiar Facts.*—**Inhabited rooms** contain much aqueous vapor. A part of it is exhaled from our lungs. If, in summer, a tumbler is filled with cold water, it becomes cold; the aqueous vapor in the air around it cools off, condenses, and forms drops of water all over the glass. If, in winter, a cold tumbler is brought into a warm room, the vapor around the glass condenses, and forms, likewise, moisture on the glass. Axes, iron safes and soda-fountains are vulgarly said to "sweat." Moisture is deposited when a person breathes against a window-pane. The aqueous vapor of heated apartments condenses on the cold window-panes and may run down as water.

*Aqueous vapor is condensed into water when in contact with cold bodies.*

*Familiar Facts.*—**Those glistening dew-drops** which you have so often admired in the early morning-sun, originate in the same manner. In clear weather, the objects on the ground cool off during the night; and at the same time the aqueous vapor in the air about them is condensed. Grass and leaves, in general all pointed objects, cool more quickly, hence they have the most dew. If the sky is cloudy, the clouds act like a screen; they throw the heat back to the earth. Then the objects do not become sufficiently cold and no dew is formed. Sometimes there is no dew, and yet the sky is serene; this is owing to winds, which bring warmer air to the objects so that they can not cool off sufficiently. As rain is aqueous vapor condensed in the air, so *Dew is aqueous vapor condensed on solid bodies.* If, during the night, objects cool off to a greater extent, the dew which is formed, freezes. We call it then Frost.

*Frost is frozen dew.*

**Read** "*Lakes, Springs, Rain, Dew, Ice,*" in "The Earth and its Wonders."

**Read** "*Atmosphere, Ocean, Rivers, Waterfalls,* in "The Sublime in Nature."—Illustrated Library of Wonders.

**Read** "*Dew and Water-vapor,*" in "The Phenomena and Laws of Heat."—Illustrated Library of Wonders.

## LESSON XXV.

### HEAT.—CONDUCTION OF HEAT.

47. EXPERIMENT.—**Strike a piece of flint** and steel together; sparks will fly off.

*Familiar Facts.*—**On a stone pavement**, at dusk, sparks may be seen when we are walking, or when a horse is galloping. In these cases, iron (the nails) has forcibly struck against stone. The sparks which we see, are minute particles of iron, or steel, which have been heated to redness by *friction.*

48. EXPERIMENT.—**Rub a key,** or a copper coin, on the floor. It will soon become heated.

49. EXPERIMENT.—**Try to ignite a match** by rubbing one gently on a piece of smooth glass. It will not burn, because there is insufficient friction; it merely glides over the smooth surface. But if rubbed against a rough surface, such as the floor or a brick, the match presses against the projecting parts of the rough surface and, owing to the friction thus produced, it becomes heated and ignites.

*Familiar Facts.*—**Wagon wheels** have so much friction at their axles, that unless properly greased, they may be set on fire. He that lets himself down by a rope has his hands blistered. On a cold day, we sometimes rub our hands together.

Saws and augurs, after being used, feel hot; a piece of India-rubber, warm. This shows that *Friction produces heat.* It shows, also, that *Motion may be converted into heat;* for friction is motion arrested.

*Familiar Facts.*—**By holding our hands** near to a heated stove they become warm. Heat of the stove passes first to those parts of the hands nearest the stove, then it gradually passes to the parts next; and so on, until all the parts of the hand are heated.

50. EXPERIMENT.—**Hold a short wire** in the flame of a burning lamp. It will be felt, that even the part of the wire which is not in the flame, is heated; and that the heat increases so that we must soon drop the wire. It is plain that the heat of the flame was imparted first to one end of the wire, and that it was communicated successively to the remaining parts of the wire. This shows that *Heat may be communicated by passing successively from any part of a body to the remaining parts. This communication is called Conduction of Heat.*

51. EXPERIMENT.—**Hold a taper,** a straw, or a thread in the flame. It may burn quite near your fingers without hurting them.

52. EXPERIMENT.—**Take up the wire again** (50 Exp.), but wrap a strip of paper, or cloth, around the end in the hand. If held into the

flame again, there is scarcely any heat felt. Tea-pots and soldering-irons have usually wooden handles. Why?

*Metals are good conductors of heat. Paper, wood, cotton, wool, fur, feathers, ashes, snow, ice, straw, and air, are bad conductors of heat.*

53 EXPERIMENT.—**Place a wire** and a piece of wood upon a heated stove, and let them remain there for a while. Both receive the same amount of heat; yet, if touched with the hand, the wire *seems* to be the warmer. This is owing to the fact that, being a good conductor, it instantly *imparts* all its heat to the hand. If you touch a cold iron bar, it instantly *takes* heat from the hand, and, therefore, *seems* cold.

*Questions.*—1. Why may ice be kept as well in a feather bed as in an ice-chest?

2. Why do mittens keep the hands warmer than gloves with fingers?

3. Why does iron feel cold in winter, and warm in summer?

4. Why are steam-chests and steam-cylinders often covered with wood?

5. Why are the walls of safes often filled with fine ashes?

6. Why do wide garments keep us warmer than tight ones?

7. Why are frame houses warmer than stone houses?

### Application of Conducting Substances.

*I. Good Conductors.*—They conduct heat very rapidly, and, therefore, they are applied in order to *diffuse heat quickly*. Thus, to boil water and roast meat, iron vessels are used. Iron stoves are heated in very little time.

*II. Bad Conductors.*—They conduct heat very slowly, but they also part with it slowly; for this reason we apply them to *retain* heat. *They serve to prevent a warm body from cooling off, and a cold body from becoming heated.*

*Familiar Facts.*—**If we wish to warm a tumbler on a heated stove,** a piece of *paper* should be placed between the glass and stove; otherwise the glass may crack. In winter, pieces of heated *wood* are laid in sleighs to keep the feet warm. *Boards* are placed on pavements, and horsemen like to have *wooden* stirrups, because wood does not withdraw the warmth from the foot.

**Cotton quilts, woolen garments, blankets and furs** keep the body warm in winter; they neither allow the warm air surrounding the body to pass off, nor do they permit the cold external air to enter. In cold countries animals have very thick *fur;* some in our latitude have thicker fur in winter than in summer. Northern birds have thick *feathers*. Feather beds are in favor with persons fond of sleeping very warm. Blast-furnaces are sometimes provided with double walls, and the space between is filled with *ashes*. A cover of *snow* retains the heat of the earth; thus it protects the winter grain from the cold. The Esquimaux build themselves huts of snow and *ice*. Tender trees, vines and pumps are covered with *straw* in winter to protect them against the cold. Ice-houses are thatched with straw, and their walls filled with saw-dust, to prevent heat from entering. Double windows are used in some houses, because the layer of *air* between them prevents the cold air from entering and the heated air from going out.

**Read** "*Heat,*" by J. Abbott. Harper & Brother.
**Read** "*Sources of Heat,*" in The Phenomena and Laws of Heat.
**Read** "*Good and Bad Conductors,*" in The Phen. and Laws of Heat.
**Read** "*Woolen Clothing,*" p. 296, in Things not Generally Known.

## LESSON XXVI.

### DRAUGHT.

54. EXPERIMENT.—**Shreds of cotton,** or small strips of paper, held over a heated stove or register, or over a lamp flame, will move upward, and, if let go, they will ascend. The air above the source of heat is heated. From the fact that boiling water runs over, and from a great many other facts (Less. XXVII), we know that heat expands bodies, and that heated air is expanded, and thus takes up more space than before, and, therefore, has less specific gravity (Less. II) than it had when cold. Now, as air rises in bubbles through water, so does heated air ascend in currents through the colder air.

55. EXPERIMENT.—**Insert one end of a rod** upright in a cork, and stand the whole on a heated stove or register. Suspend from the top a band of paper, cut in the shape of a spiral, the upward current of hot air will cause it to revolve.

56. EXPERIMENT.—**Bring a thermometer** near the floor of a room; then, near the ceiling. It will be seen that near the ceiling the air is warmer than below. *Heated air rises.*

Why do balloons, smoke and steam rise? (See Lesson II.)

57. **Experiment.—If a window** in a heated room be opened above and below, the flame of a burning candle, held in the opening above, will be blown *from* the room; if held in the opening below, *into* the room.

*Familiar Facts.*—**The same** may be observed with cotton shreds in place of the flame. This shows that the colder air from out-doors rushes into the room from below, while the heated air of the room flows out above. The colder air is confined to the lower parts of a room, because it has greater specific gravity than heated air. Wherever a fire is burning, a current of air, or *draught*, is produced. A draught is also noticed when passing from the sun into the shade, for where the sun shines, warmer air ascends, and is replaced by the colder air from below. Chimneys serve to increase the draught, because they enclose a tall column of heated air, which has less specific gravity than the outer, colder air. The latter presses in with increased force proportionate to the height of the chimney. If a handkerchief be tied around the small openings under the burner of a lighted lamp, the flame will be extinguished. The same happens, also, if the top of the chimney is covered with a piece of glass; in this case the draught is stopped because the heated air can not pass out, and consequently no fresh air come in.

*Heated air rises; colder air flows in to take its place.*

*Familiar Facts.*—**Near heated ground,** the air ascends and is replaced by colder air. This causes our atmosphere to be in constant motion. The currents thus produced are called *Winds.*

*Application.*—Chimneys (in lamps, stores, factories, &c., &c.) Ventilation of rooms and halls.

**Read** "*Draught and Ventilation,*" p. 269, in Things not Generally Known.

**Read** "*Winds and Currents,*" p. 279, in Things not Generally Known.

**Read** "*Does the Sun Influence a Fire,*" p. 267, in Things not Generally Known.

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## REVIEW.

LESSON XXIV.—

1. Heat changes liquids into Vapors. Vapor of water is called Aqueous Vapor. The process is called Evaporation.

2. Aqueous vapor coming in contact with cool air, forms *Fog*. Fog is clouds near the earth. Clouds are fog in the higher regions of air.

3. Aqueous vapor, in contact with cool air, forms *Fog;* in contact with cold air, *Rain;* with cold, solid bodies, *Dew;* with intensely cold air, *Snow*. *Hail* is, perhaps, frozen rain. *Frost* is frozen dew.

## LESSON XXVII.

### EXPANSION BY HEAT.—THERMOMETER.

58. EXPERIMENT.—**Hold a fine glass tube, partly filled with water, over a flame of a lamp; the water will be seen to rise as it becomes heated. Warm water takes up a larger space than cold.**

*Familiar Facts.*—**A cold tumbler** placed on a heated stove will crack at the bottom. The heat expands the glass; but glass is brittle (what is meant by "brittle?"—Lesson IX), and so the tumbler must break. How may it be prevented from cracking? (Lesson XXV, p. 95.) A bladder, filled with air and tied up at the end, expands if near a hot stove or register. The air inside becomes heated, and heated air takes up a greater space than cold air. A flask with ground glass-stopper is sometimes difficult to open; if it be gently heated around the neck the stopper may be taken out without difficulty. The rails on a railroad-track are laid so that their ends shall be at a slight distance from each other; in summer their ends are very nearly together; in winter they are farther apart. Tires are heated red-hot before they are placed on the wheels, for they are then wider, and, on cooling, fit tight to the wheels. Chestnuts and pop-corn, when exposed to heat,

burst open; the heated air inside expanding, forces its way through. Heavy rocks, and the walls of houses, may crack. The reason is this: They expand in summer and contract again in winter.

*All bodies are expanded by heat; they contract again by cold.*

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Here is an instrument called "Thermometer." The silvery substance in it is one of the few metals which have the liquid state at ordinary temperature; at an intense degree of cold—such as Arctic explorers experience—it freezes into a solid mass. Its name is Mercury, or Quicksilver If the mercury is heated, it expands, and rises in the tube, simply because it has no other place to which to go. On cooling, it contracts and falls. It may be heated by our atmosphere, that is, by the sun; or by hot water; by steam; by heated oil, or merely by the natural warmth of our hand placed upon it. On examining the thermometer, you notice that it consists of a glass tube with a bulb below. Both tube and bulb are closed. The bulb and a portion of the tube are filled with mercury. Above the mercury is a vacuum. The vacuum is obtained by heating the mercury to a very high degree; while it then stands very high,

the tube is fused at the highest point of the mercury. This closes the tube so that no air can get in. As the source of heat is removed, the mercury falls slowly, leaving a vacuum behind. The frame is not an essential part of the thermometer. A little above the bulb is a point, marked Freezing Point. Everywhere on the earth, ice melts at the same degree of temperature. So, after the tube is sealed and cooled off, it is placed in melting ice. Immediately the mercury sinks, because the cold contracts it. It occupies now a much smaller space, and when it has settled, its lowest point is carefully marked, either on the frame or by etching it on the glass tube. This point is called the "Freezing Point." It has also been found that all over the earth, water, in low countries, boils at the same temperature. So the thermometer is now held upright in the hottest steam issuing from boiling water. Heat expands all bodies; hence the mercury expands and is seen to rise in the tube. The point to which it ascends is carefully marked; it is the "Boiling Point." The space between the two points has been divided into degrees. By means of these degrees, we are enabled to indicate the temperature which a body has acquired.

**Read** "*Expansion—Thermometer*," in "The Phenomena and Laws of Heat."

## LESSON XXVIII.

### THERMOMETER COMPARED WITH BAROMETER.

59. EXPERIMENT.—**If the palm of the hand, after being rubbed a little so as to be perfectly dry, is held to the thermometer-bulb, the mercury will rise to a point which marks the Blood-heat of the human body.** It happens to be indicated on our thermometers by the number 97. This is owing to the fact, that in our country, and also in England, the space between the freezing and the boiling points is measured by very small degrees, of which there are 180 between those two points. Fahrenheit, a philosophical instrument-maker, divided that space into 180 degrees. He commenced counting, however, not at the Freezing-point, but at a point below, which is the zero point. The freezing-point thus happens to be at 32°; this causes the boiling-point to be marked 212°. On the continent of Europe, the Freezing-point is marked 0°; the Boiling-point 80°. That is, the space between the two points is divided into only 80 degrees. Each degree of this kind is much larger (how many times as large?) than one of the former kind, the Fahrenheit. From the name of the French philosopher who arranged

this scale, its degrees are called degrees *Reaumur.* Thus 80° *R.* is equivalent to 180° *F.* Far more convenient than either of the two preceding scales is the one of Celsius. He divided the space between the freezing and the boiling points into 100 degrees. The use of this division is gradually spreading. According to it, 100° *C*=180° *F*=80° *R*.

Explain the following table:

| *Reaumur.* | *Centigrade (Celsius).* | *Fahrenheit.* |
|---|---|---|
| 80° | 100° | 212° |
| 40° | 50° | 122° |
| 20° | 25° | 77° |
| 0° | 0° | 32° |
| $-14\frac{2}{9}$° | $-17\frac{7}{9}$° | 0° |
| −40° | −50° | −58° |

The healthiest temperature for any room is about 65° *F.* Our rooms should not be heated beyond that in winter. Thermometers should be placed at equal distance from stove, or fireplace, and the windows, so as to show the mean temperature of the air.

*Questions.*—If in New York the mercury stands at 80° above zero, how would the same temperature be indicated in Paris (according to *C.* degrees)? How in Berlin (according to *R.* degrees)? By what numbers would the blood-heat point be indicated according to those scales? By what number is the point of healthiest temperature indicated in *C.* and *R.* degrees?

### Thermometer and Barometer Compared.

Four points in common:

1. Both instruments consist of a *glass tube.*
2. Both have *mercury* in their tube.
3. Both have a *vacuum.*
4. Both have a *graduated scale.*

Four points of difference:

1. The thermometer-tube is *closed above and below;*
   the barometer tube is *closed above but open below*, so that the pressure of air may reach the mercury within it.
2. In the thermometer-tube, the mercury rises and falls on account of the effects of *heat and cold;*
   in the barometer-tube, the mercury rises and falls on account of the increase or decrease of *air-pressure.*
3. The thermometer has a scale of *degrees whose size is arbitrary* and may be different in different thermometers;
   the barometer has a scale of *inches*, and fractions of inches; its scale is of *less extent*, and only at the *upper part* of the tube.
4. Mercurial Thermometers may have *any length;*
   mercurial Barometers have *uniform length.*

## LESSON XXIX.

### THE ATMOSPHERIC ENGINE.

1. **If we look at a sewing-machine** while it is in motion, our attention is immediately called to a long, upright rod, made to move up and down by the stroke of the foot. The rod being fastened to a wheel, it is evidently its up and down motion that causes the motion of the wheel and with it, that of the machine. You need but fasten a rod to the edge of a toy-wheel, and you may demonstrate the same. Motion in a straight line—*rectilinear* motion—is thus converted into *circular* motion.

2. This was known thousands of years ago; but, strange to say, the principle upon which the steam-engine is founded, was not thought of until about 1690, A. D. At that time, Professor Papin, an exiled Frenchman living in Germany, published a little work, in which he says: "There is a property peculiar to water, owing to which a small quantity of that liquid, if heated and converted into steam, acquires a force of elasticity which much resembles that of air. When cooled down, it returns to the liquid state, and loses its elasticity. I am, therefore, inclined to believe

that machines may be constructed which are moved by the application of heat to water."

3. These words laid the foundation for the greatest change which human society ever experienced. The machine that effected this change has benefited humanity more than all the gold mines in the world. The steam-engine not only reveals to us the hidden treasures of the earth; "it can engrave a seal; crush masses of obdurate metal like wax before it; draw out, without breaking, a thread as fine as a gossamer, and lift a ship of war like a bauble in the air. It can embroider muslin and forge anchors; cut steel into ribands and impel loaded vessels against the fury of the winds and waves." And when it flies with the rapidity of a bird, over land and water, hurling dense masses of steam and smoke into the air, does it not look like some gigantic monster that contains the strength and the power of thousands of men? Well may we admire the genius of man that can turn one of Nature's simplest forces to such wonderful account.

4. The simplicity of Papin's statement is demonstrated by his own application. Knowing that steam was elastic like air (Lesson X), he immediately proceeded to the construction of an apparatus which, although its practical usefulness was impeded by its slowness, was the first steam-engine ever built.

60. EXPERIMENT.—**Papin's apparatus** may be illustrated by a test-tube (one of tin is preferable inasmuch as glass breaks easily,) as shown in Fig. 22. A small disk of wood, with a packing of thread around it to make it fit tight, is made into a piston, *P*, moving in a tube nearly air-tight, and attached to a rod. The tube is then filled with water about an inch high, which is made to boil over a flame after the piston is carefully placed in the tube. The generation of steam causes the piston to rise. The steam escapes through a small hole, *E*, made in the upper part of the tube. Between the water, when boiling, and the piston there is no air; the space is filled with steam. On immersing the tube in cold water, the rod descends again, because the steam below the piston is condensed by the cold, and because a vacuum is thus formed between the piston and the surface of the heated water. What is it that forced the piston down? The answer is: "Atmospheric Pressure." (Lesson XI.)

FIG. 22.

5. In place of the small tube of this experiment, Papin used a large iron cylinder, with proper piston and piston-rod. We can readily imagine how, by throwing, at regular intervals, a stream of cold water on the cylinder, he produced an up-and-down motion of the rod; and how his machine must needs have been slow—too slow to be

practically applied. A steam-engine built upon the principle of Papin's—that is, one not worked by the expansive force of steam, but merely by atmospheric pressure—is not a steam-engine. It is an "Atmospheric Engine."

6. **Captain Savery,** an Englishman, constructed at about the same time, an apparatus in which the steam served the purpose of raising water. The steam was generated in a separate boiler, and thence led into a chamber where it was condensed by cold water flowing over the chamber. The apparatus, however, was very imperfect, and used only for pumping water. Still, his was the merit of having constructed the first Atmospheric Steam-Engine that received practical application.

7. **Thomas Newcomen,** a hardware man, and John Cowley, a glazier, both Englishmen, by their brilliant invention, completely eclipsed Savery's engine. They improved upon Papin's plan in this, that they generated the steam in a boiler—not in the cylinder—and that they condensed it, not by cooling the boiler from without, but by forcing a jet of cold water into the steam. The machine was put to immediate use in the coal-mines of England; and it is sometimes used even at present, in places where a great mass of water is to be pumped out. Its construction is very simple.

8. It consists of the boiler, *A* (Fig. 23), where the steam is generated, and the cylinder, *B*, which is

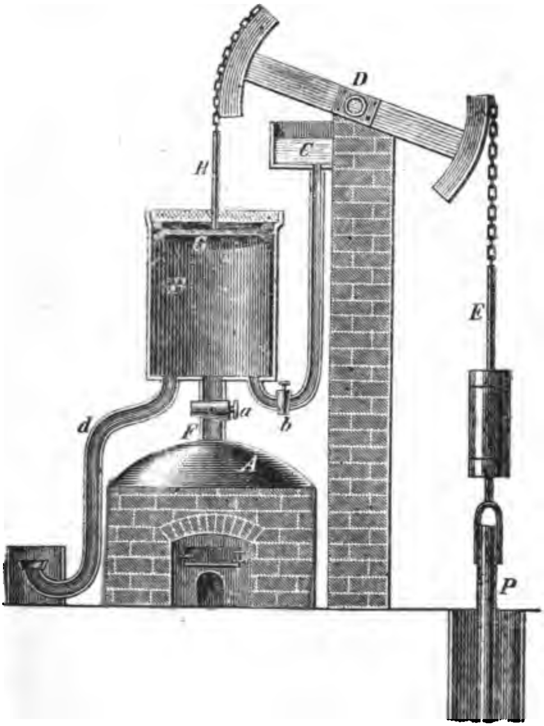


FIG. 23.

connected with the boiler by means of the pipe, *F*. When steam has entered the cylinder and the piston, *G*, is raised, the stop-cock, *a*, is closed. This shuts off the connection between the boiler and the cylinder. The stop-cock, *b*, is then opened, and a jet of cold water from the small reservoir, *C*, is thrown into the cylinder. This

condenses the steam in the cylinder; a **vacuum** is formed below the piston, and atmospheric pressure forces the piston down. The water from the condensed steam flows off through the pipe, *d*, into a reservoir with water. (At the end of *d* is a valve opening outward.) By means of an iron chain, the piston-rod, *H*, is attached to a working-beam, which swings on the pivot, *D*, and which is connected at the other end with the rod *E*. This rod is raised when the piston descends. When the stop-cock, *a*, is opened again, the steam rushes again into the cylinder; but as the force of pressure of the steam scarcely exceeds that of the air over the piston, the piston would not rise, were it not for the heavy weight attached to the rod, *E*. This weight falls whenever steam is let in under the piston, *G*; and in falling, forces one arm of the working-beam down, causing, at the same time, the piston at the other arm to rise. The rod *P* is the piston-rod of a pump, and is fastened to the weight.

*In the Atmospheric Engine the piston is raised by Gravity, and lowered by Atmospheric Pressure.*

State the principal points of Papin's engine; of Savery's; and Newcomen's.

Read "*H. Potter*," in "Inventions and Discoveries," by Tetuple. London: Groombridge.

## LESSON XXX.

### THE STEAM-ENGINE.

1. **Half a century** had passed away. Newcomen's engine had been introduced into most of the coal-mines of England, when, in the winter of 1763, a young mechanic, James Watt, in Glasgow, was employed by the University of that city to repair one of Newcomen's engines. The task which this man of uncommon mind was about to undertake, marks a new era in the history of steam-power, an era that finally resulted in the perfection of a machine which is an element of modern civilization. On trying the engine after he had repaired it, young Watt perceived that it was very imperfect. The principal defect consisted in this, that the machine used a great deal more steam than was needed for the motion of the piston. For when the stream of cold water was thrown into the cylinder, the steam was condensed; but at the same time, the cylinder was cooled down to such an extent, that when fresh steam was admitted again, a great quantity of it was wasted in reheating the cylinder; and thus there was a loss of money in direct proportion to the amount of fuel necessary for producing the quantity of steam equivalent to the quantity

wasted. On calculating the loss, it was found that ¾ of all the fuel used was wasted; that is, employed in reheating the cylinder. The question with Watt now was, How can the cylinder, instead of being cooled, be kept permanently hot? In other words, How can the steam be condensed without at the same time cooling the cylinder?

2. Watt's genius solved the problem by an invention of surprising simplicity. He condensed the steam in a separate chamber, the *condenser*. It stood in a chest filled with water, and was connected with the cylinder by means of a pipe. Thus the steam could be condensed without cooling the cylinder, by simply leading it off. The immediate result was the saving of ¾ of the fuel.

3. But Watt did not stop here. He noticed that the air entering the heated cylinder as the piston went down, also cooled the cylinder. This caused a waste of steam, as the cylinder, in order not to condense the fresh steam entering, had first to be reheated to 212°. To remedy this, he dispensed with the air entirely, in providing the cylinder with a cover pierced in the center so as to admit the piston-rod air-tight. The air (atmospheric pressure) could now no longer act upon the piston; how then was the piston to descend? It was made to descend by allowing steam from the boiler to enter *above* the piston, through a pipe connecting the boiler with the upper part of the

cylinder; and to pass out again through a pipe connecting the cylinder with the condenser. Thus while there was a vacuum established in the lower part of the piston, steam was admitted into the upper part; the upper part then being made a vacuum by leading the steam off into the condenser, fresh steam was admitted into the lower part and forced the piston up. By this improvement, the steam not only served as a ready means for obtaining a vacuum, as in Newcomen's engine, but its expansive force was also made use of, and from that time Watt's engine was no longer an atmospheric, but a steam-engine.

4. The atmospheric engine was "Single Acting;" it did work only while the piston descended; the rise of the piston, as we remember from the preceding lesson, was effected by gravity. The power obtained by this machine was so small that it could not overcome the resistance of a wheel, and, therefore, it was used mainly for pumping water out of coal-mines.

5. It will now be readily understood, that by admitting the steam alternately above and below the piston, Watt made the steam-engine "Double Acting," and this was, perhaps, the most important of all his improvements. For now, circular motion could be produced, without which no locomotive or steamboat could ever have been thought of.

Watt died in 1819, honored and admired by all who knew him. Within a short time after his death, five large statues were erected to his memory.

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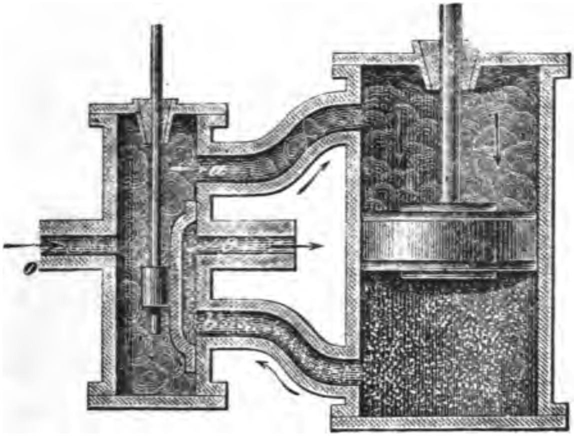
6. In all the engines constructed by Watt, the power of the steam was low; it amounted scarcely to more than 1¼ atmospheres (1¼ as much as the pressure of our atmosphere; that is 1¼ times 15 pounds to the square inch of surface). The alternate condensation of steam on either side of the piston was, therefore, the only means of obtaining the up-and-down motion of the piston; for the feeble expansive force of the steam was totally insufficient to overcome the counter-pressure of the atmosphere. But by employing steam of greater expansive force—that is, steam capable of exerting a higher pressure—one might dispense with the condenser. It was reserved to an American, Oliver Evans, in Philadelphia, to introduce steam of a higher pressure as motive power. Engines usually having a steam-pressure of from 3 to 15 atmospheres (45 to 225 pounds of pressure to the square inch), are called *High Pressure Engines;* those working with a lower pressure, *Low Pressure Engines.*

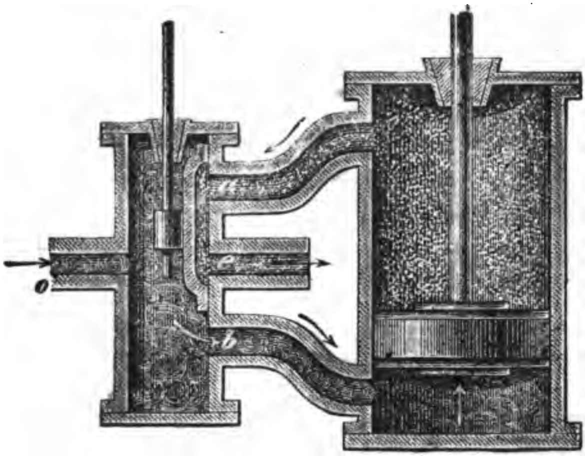
**7. The admission of steam into the cylinder** is now accomplished by means of a *sliding-valve.*



Steam-Chest. FIG. 24. Cylinder.

It is enclosed in a square box, called the steam-chest (See Fig. 24), which is attached to one side of the cylinder. When the steam from the boiler reaches the steam-chest through the opening, *o*, it fills the chest at once, and, as the sliding-valve keeps the opening, *b*, closed, it presses through the opening *a* into the cylinder. There it fills the upper part and forces the piston down. This it does because a vacuum has been formed on the other side of the piston, or, as is the case in High Pressure Engines (see Fig. above), by the immense expansive force of the steam. At the same time, however, the sliding-valve (which rises when the piston-rod descends, and descends when the pis-

ton-rod rises,) has moved upward, and shuts off the steam from *a* (see Fig. 25); the steam must




Steam-Chest. FIG. 25. Cylinder.

now enter through the opening *b* and force the piston up. Meanwhile the old steam above the piston passes through *a* and *e* into a tube leading to the condenser. In a steam-engine which has no condenser, as, for example, the locomotive, the old steam passes through *e* into the air. After the piston has arrived above, the process is renewed, owing to the sliding-valve having a motion opposite to that of the piston; thus steam is admitted alternately above and below the piston which, as every one knows, moves in a vacuum, or rather, in a space filled with steam.

Steam-engines with steam of very high pressure usually have no condensing apparatus.

8. When we look at a locomotive rushing past us at full speed, we notice a horizontal iron rod moving back and forth. The rod connects two large wheels, and runs at one end in a wide brass cylinder. Next to this cylinder is the steam-chest, a small square box. It is in the cylinder that the motory power is imparted to the engine. In addition to these things, we see a great many wheels, pipes and rods; but they mostly serve minor purposes. The main parts of the locomotive are the steam-chest, cylinder, piston, piston-rod, the large wheels, and the boiler.

9. The steam, by means of the sliding-valve, causes the back-and-forth motion of the piston in the cylinder; by this, it causes the back-and-forth motion of the piston-rod; and by this, the revolution of the large wheels. The wheels roll on the track; they cause the locomotive to move onward, and the locomotive pulls the cars attached to it.

**Read** "*James Watt,*" in "Pursuit of Knowledge," Vol. II. New York: Harper & Bros.

**Read** "*The Locomotive Engine,*" by C. Colburn. H. C. Baird, Phila.

**Read** "*The Steam-Engine,*" by David Read. Hurd & Houghton, New York.

**Read** "*The Railway and its Cradle*"—"*The Youth of James Watt*"—in "Inventions and Discoveries." Groombridge & Sons, London.

## LESSON XXXI.

### REVIEW.

LESSON XXIII.—

1. The motion of a body produces vibrations in the air which, if they impress the ear, give us the sensation of sound. Sound, therefore, is merely the effect of a vibrating motion upon our ear.

LESSON XXV.—

2. Heat may be communicated by passing successively from one part of a body to the other parts. This mode of communication is called *Conduction of Heat.*

LESSON XXVI.—

3. Heated air rises, because it has less specific gravity than cold air. This fact causes *Draught* and *Winds.*

LESSON XXVII.—

4. All bodies are expanded by heat; and contracted by cold.
5. What we call "Heat," is merely a vibrating motion among the minute invisible parts (molecules) of a heated body. We can not see that vibrating motion, but we can feel it.
6. What we call "Sound," is merely a vibrating motion of masses. We can neither see nor feel that vibrating motion, but we can hear it.

7. As sound is the effect of vibratory motion upon the *ear*, so heat is the effect of vibrating motion upon our *nerves*.

LESSON XXIX.-

8. In the Atmospheric Steam-Engine, the piston is raised by *Gravity;* and forced down by *Atmospheric Pressure.*

LESSON XXX.—

9. Low Pressure-engines have a steam-pressure of not more than 1½ atmospheres. The steam-pressure in High Pressure-engines may go as high as 15 atmospheres.

10. In the locomotive, steam causes (by means of a sliding-valve) the back-and-forth motion of the piston in the cylinder; and by this motion, the back-and-forth motion of the piston-rod; and by this, the revolution of the large wheels. The wheels roll on the track; this causes the locomotive to move onward and draw the cars attached to it.

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11. On dropping a stone to the floor, the floor and the air over the floor, commence vibrating. This shows that *Force* (Force of Gravity in this case) may be converted into *Motion.*

12. The motion of a train of cars heats the axles and wheels of the cars. This shows that *Motion* is convertible into *Heat.*

13. Heat expands all bodies (Less. XXVII); and as expansion (the work done by heat) is motion, we may say that *Heat* is also convertible into *Motion*. (Thermometer.)
14. Heat expands water into steam. Steam expands still farther. The particles of steam, therefore, are in continual motion. The effect of this motion is the Expansive Force of Steam. This shows that *Motion* is convertible into *Force*. (Compare Less XXII, Review.)
15. The Expansive Force disappears as soon as the steam has moved the piston of the engine. The motion of the piston is the *work done* by the steam. Thus, in this case, *Force* is converted into *Motion*. (Compare No. 14, above, and Less. XXII, No. 13.)
16. *Force of Pressure* is convertible into *Motion of Masses*. (Wind—Barometer—Pumps.)
17 From all the preceding, we see that
   *a*. Force is convertible into *Motion*. (The pump.)
   *b*. Motion is convertible into *Heat*. (Friction.)
   *c*. Heat is convertible into *Motion*. (Thermometer.)
   *d*. Motion is convertible into *Force*. (Expansive Force of Steam.)

## LESSON XXXII.

### LIGHT—ITS SOURCES—DIRECTION.

*Familiar Facts.*—**While the sun shines**—that is, during the day—it is light; we can see objects at a distance. But we can not see objects at night, for then it is dark; the sun is on the other side of the earth. The light of the stars, or flashes of lightning, may somewhat relieve the darkness of night; glow-worms may feebly illuminate our immediate vicinity. If we rub a match in the dark against the hand, the phosphorus will shine on the hand. This property is called Phosphorescence. Glimmers of light are also noticeable in decaying animal and vegetable substances. Two pieces of sugar, after being rubbed together, also emit light. Candles, oil and gas, at times, also, torch-lights, are our usual means of illumination. But our greatest luminary is the sun.

1. *The Sun and the Fixed Stars, Electricity, Phosphorescence and Burning Substances are Sources of Light.* The sun, stars, lightning, phosphorus, glow-worm and flame are *Self-luminous Bodies.*

*Familiar Facts.*—**The moon** sends light to us; so do other planets. But this light is not her own;

she receives it from the sun, the same as the other planets do. She is invisible to us, except when the sun's light falls upon her. When the room is dark, a book upon the table can not be seen; neither can the table, nor the desks, nor the streets, nor anything else. None of these objects is *self-luminous;* that is, in order to be seen, these objects need light from a self-luminous body.

2. *Neither the planets, nor most of the objects surrounding us, are self-luminous bodies.*

*Familiar Facts.*—**If we close our eyes** we can not see. Nor can persons who were born blind, or have become blind from accident or disease. In order to see objects behind us, we must turn around; to see things above us, we must turn our eyes upward.

3. *Bodies not self-luminous are visible only when they receive light from a self-luminous body; and then only, if a part of that light forms an impression on our eye.*

Pencils, crayons, glass, water, ice, trees, houses, and all other objects are seen by us, because when light falls upon objects, a portion of the light is diffused from their surface in all directions, and because a small portion of that diffused light enters our eye and forms an impression on the retina. From our room we see objects out-doors very clearly; but when looking from without, objects in the room are not seen so well. The amount of light diffused in a room is much smaller than that diffused out-doors.—It is light in daytime, although it may be very cloudy. The clouds receive all the light from the sun, and diffuse a portion of it.

61. EXPERIMENT.—**Place a large paste-board** (with a small hole in it) a few inches from the blackboard. Light a candle and place it in front of the hole in the pasteboard. A bright spot will be seen on the blackboard. It is a spot illumined by the rays of the light that pass from the flame through the opening. The direction from the flame through the hole to the illumined spot is that of a straight line. Let the flame be moved about, the spot will move also.

*Familiar Facts.*—**Through the cracks** in the shutter of a darkened room, rays of light are observed to enter in straight lines. The hunter levels his gun at a squirrel in the direction in which the rays of light diffused from the squirrel enter his eye. Opera-glasses and telescopes have straight tubes.

4. *Light emanates from self-luminous bodies in all directions, and travels in straight lines.*

**Read** "*Sun, Moon and Stars,*" in "The Wonders of the Heavens"—Illustrated Library of Wonders.

**Read** "*Light and Color,*" in "The Earth and its Wonders."

**Read** "*The Eye,*" in "The Human Body"—Illustrated Library of Wonders.

## LESSON XXXIII.

### RADIANT AND SPECULAR REFLECTION.

**During the daytime,** sunlight is diffused in the atmosphere as well as in the air of our rooms, whether the sun is visible or not. Some of this light in the air falls upon the walls and upon the objects in the room; and the walls, as well as the objects, *reflect* (throw back) that light in all directions. They reflect it thus: Every point of their surface *radiates* the light in all directions; hence any point of this surface may be seen by a person in the room, whatever part of the room he may be in, provided that a portion of that reflected light strikes his eye.

*Familiar Facts.*—**Here is a pencil.** What enables us to see it? It is not a self-luminous body; but there is diffused light in the room, and as the pencil has a more or less rough surface, every point on that surface receives some of this diffused light, and in turn *reflects* some of it. It does so by *radiating the light in all directions.* Of this radiated light, a portion enters our eye, and we say "we see the pencil," and may then describe it.

*We see a looking-glass*, owing to the light which is reflected from it by radiation. True, its surface

is smoother than that of the pencil, or of most objects; yet even in a looking-glass there are very many uneven places, from every point of which light is reflected by radiation. Were it not for that, we would not see the glass at all. The surface of a perfect mirror is invisible.

*All bodies reflect light by radiation.* We call this *Radiant Reflection of Light.*

62. EXPERIMENT.—**If an India-rubber ball be thrown upon the floor in the direction in which a ray of light would pass through a crack on the floor of a darkened room, the ball will rebound, and may be made to strike the wall opposite the crack. Let the place where it strikes the wall be marked. Now lay a looking-glass upon the bright spot on the floor of the darkened room (the spot is caused by the rays of light entering through the crack), and it will be seen that the rays, like the India-rubber ball, rebound to where the ball struck the wall. Evidently the rays are reflected by the looking-glass. Any other highly polished surface would have caused the same reflection.**

All this shows that *there are objects which not only reflect light by Radiant Reflection in all directions, but which, in addition, reflect an extra amount of light in certain definite directions.* We call this *Specular* (mirror-like) *Reflection of Light.*

*Familiar Facts.*—**Burnished metal plates**, polished wood, the surface of water or mercury, the coating of mercury in looking-glasses, and even common glass plates when viewed in a very oblique position, exert both, "Radiant" and "Specular" reflection of light. *Objects with polished surface reflect light radiantly and specularly.*

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## Light reflected Radiantly compared with Light reflected Specularly.

Four points in common:

1. Both have emanated first from a self-luminous body.
2. Both have been thrown back from the surface of bodies not self-luminous.
3. Both have their rays travel in straight lines.
4. Both may enter the eye.

Three points of difference:

1. Radiantly reflected light proceeds from the surface of *all* bodies;
   Specularly reflected light only from the surface of *highly polished* objects.
2. Radiantly reflected light is thrown back from a surface in *all directions;*
   Specularly reflected light is thrown back from a surface only in *certain directions.*
3. Radiantly reflected light enables us to see *objects;*
   Specularly reflected light enables us to see *images* of objects.

# LESSON XXXIV.

## VISIBLE DIRECTION.—REFRACTION.

*Familiar Facts.*—1. **When a person is hit** with a stone he does not seek the person who threw the stone, in the direction in which the stone flies, but in the direction from which it comes. Thus, he whose forehead has been struck by a stone in a downward direction, looks upward for the perpetrator; he supposes him to be in the direction from which the stone came. If struck by a stone in an upward direction, he will look downward to find the evil-doer.

It is the same with a ray of light.

2. **A boy looking at a steeple,** receives its topmost ray of light in downward direction. Imagine

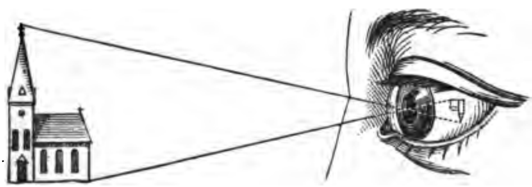

FIG. 26. Image Inverted.

this ray to be extended after passing through the opening in his eye (Fig. 26).

Since light travels in straight lines (Lesson XXXII), the ray crosses the *lower part* of his eye in a downward direction. The lowest ray coming from the foot of the steeple would, if extended, traverse the *upper part* of his eye in upward direction. But if, turning round and then bending his head down to his knees, he looks at the steeple from between his knees (Fig 27), the

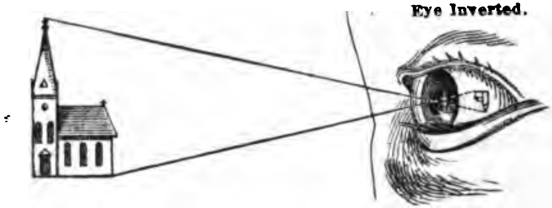


FIG. 27. Image Upright.

topmost ray will, if extended, pass downward through the *upper* part of his eye; and the lowest ray, upward through the *lower* part of his eye. In this case he would see the steeple *inverted*, were it not for the fact that *the eye sees an object, or any part of an object, in the direction from which the rays of the object come. All bodies appear to be situated in the direction from which their rays enter the eye.*

63. Experiment.—**Immerse a pencil** in water perpendicularly; it looks as straight as before. But when immersed obliquely, it appears bent, or broken. Oars, when partly immersed, present

the same appearance. When the pencil is out of the water, we see it by means of the light diffused from it (Lesson XXXIII). Consequently, when the pencil is partly immersed, we see the portion above the liquid for the same reason. The light diffused from the immersed portion, however, must first travel through the water, and then through the air. Now, since the immersed portion seems to be bent, it follows that the rays diffused from it are bent; that is, they travel in straight lines through the liquid, but on entering the air, they are made to deviate from their straight course. But the eye is in the habit of following the direction of the rays, and must see the pencil *bent* simply because the rays coming from it are bent.

Let *a b* be the pencil partly immersed; the part immersed, *a c*, appears to be at *d c*, because the ray coming from *a*, which ought to pass out in the direction of *a b*, is made to deviate from its course when leaving the water at *c*, and enters the eye in the direction of *d e*. The eye, believing the point *a* to be in the direction from which its ray comes, sees the point *a* actually as being at *d*. The same takes place with the other rays entering the eye; hence the whole part *a c* is seen as being at *d c*.

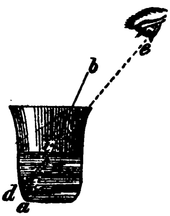

FIG. 23.

64. EXPERIMENT.—**A coin** placed on the bottom of a filled tumbler, is seen in its true direction if viewed perpendicularly; but if viewed obliquely, it will be seen in a more elevated place.

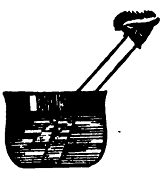

FIG. 29.

*Familiar Facts.*—**Owing to refraction of light,** the bottom of clear waters appears to be more elevated than it really is; that is, water often appears less deep than it in reality is. This must be taken into account by persons bathing, so that they may not go beyond their depth.

*Rays of light, on passing obliquely through substances of different densities* (such as air and water, or glass and water), *deviate from their straight course; they are bent. This deviation is called Refraction of Light.*

# LESSON XXXV.

## PRISMS.—LENSES.

65. EXPERIMENT.—**On a blackboard make a mark in the shape of an arrow, and look at it through a glass prism, which should be held so that only one edge of it is directed upward (Fig. 30). The arrow will**

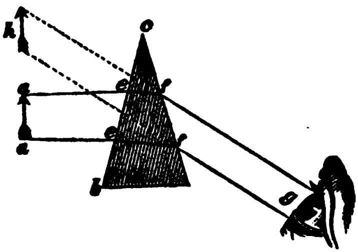

FIG. 30.

**then be seen as being above its true place.** The reason is this: Rays of light, *a e*—we take but two for the sake of simplicity—diffused from the arrow, strike the surface, *b c*, obliquely, and are, therefore, refracted to *f* (Less. XXXIV). On passing from the glass prism at *f*, they are again refracted, and enter the eye which is stationed at *g*. But the eye follows the direction of the refracted rays (Less. XXXIV); consequently it sees the arrow as being at *h*.

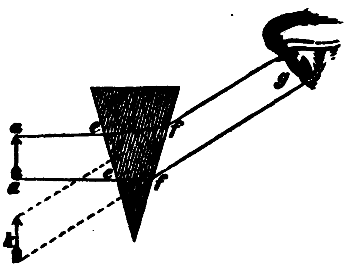

FIG. 31.

66. EXPERIMENT.—**Now look at the arrow on the blackboard through the**

prism inverted (Fig. 31); that is, placed so as to present two edges upward. The arrow will then be seen *below* its true place. The reason of this is the same as before. The rays *a e* are refracted to *f*; consequently the arrow is seen as being at *k*.

**If now we place two prisms together,** as in Fig. 32, rays diffused from the arrow and entering

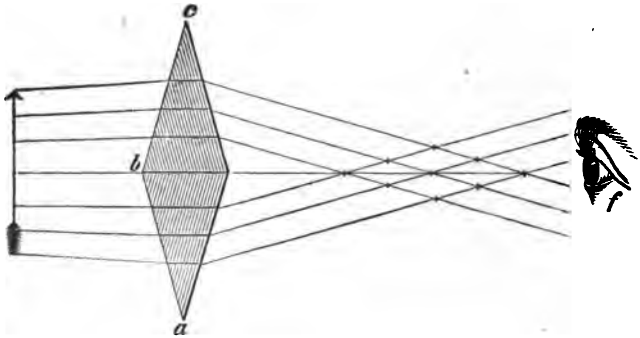


FIG. 32.

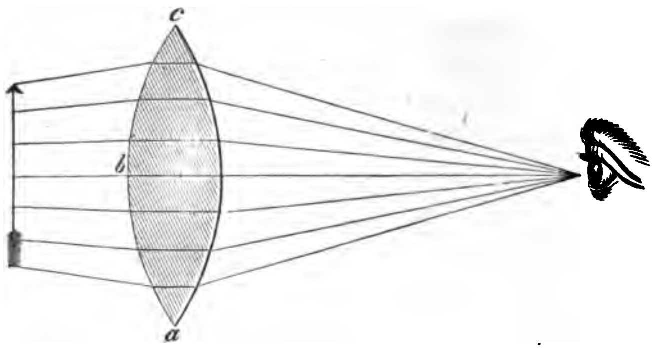


FIG. 33.

the glass surface, *a b c*, will, in like manner, be refracted twice, and meet each other in several

points behind the prism. In order that the eye of a person situated at *f*, might receive all these refracted rays, and thus be able to see the whole arrow through the prisms, it would be necessary to have these rays blend into a common point. To do this, we must have the surface, *a b c*, curved (Fig. 33); that is, we must have a curved glass in place of the prisms. Such a curved glass is a *convex Lens*, commonly called a *Burning-glass*. For it not only brings rays of light to a common point, the Focus, but at the same time it blends rays of heat into a focus. In consequence of this, a match ignites, and a hole is burnt in a piece of paper, if either of these objects be held in the focus.

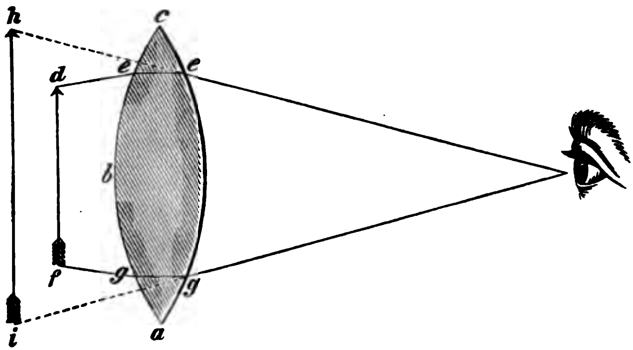


FIG 34.

**The arrow**, as viewed through a lens, is seen larger (Fig. 34); that is, it is magnified, because—

taking the two extreme rays for the sake of illustration—the rays, *d e* and *f g*, refracted to the eye, are seen as coming from the points *h i*. (Why? Lesson XXXIV, p, 130.) The common Burning-glass, therefore, is also called *Magnifying-Glass.*

*An object in front of a convex lens is seen magnified by an eye placed behind it.*

*Application.*—The lenses in spectacles; opera-glasses and telescopes; all magnifying glasses.

**Read** "*Magnifying and Burning Glasses,*" in "Pursuit of Knowledge," Vol. II. Harper & Bros.

**Read** "*Lenses,*" in "The Wonders of Optics"—Illustrated Library of Wonders.

**Read** "*How to View Pictures,*" p. 248, in—"*Spectacles,*" p. 250—in "Things not Generally Known."

# LESSON XXXVI.

## COLOR.

66. Experiment.—If a large pasteboard with a small hole be placed facing the sun; or if a room be darkened and only a few rays of light admitted through a crack in the shutter, these rays will pass to the floor and there form a spot of white light. But if a prism[1] be held before the crack or before the hole in the pasteboard, the rays of light will be refracted (Less. XXXIV), and spread out in the form of a long band. Instead of being white, this band will be colored. The colors of the rainbow may be distinguished in it; viz.: *Violet, indigo, blue, green, yellow, orange and red.* The colored band is called the Solar Spectrum; and this spreading out of light

1. **A prism** which is to show the refraction of light, may be of solid glass, or, if such a one can not be had, it may be constructed in the following manner: Procure two strips of common glass, having the shape of a rectangle, each of the same size, about 5 inches long by 1½ inches wide. One of the long edges of each is heated over an alcohol flame; both edges are then cemented together with sealing-wax, allowing a distance of 1½ inches between the two remaining long edges. The ends of the vessel thus formed are closed by triangular pieces of thin board, measuring 1½ inches on each side, and which are likewise cemented to the glass. Water is then put in, and when used, the prism is held so as to have the long cemented edge below.

FIG. 35

is called Dispersion. If the spectrum be made to fall upon a mirror, it will be reflected in straight lines like ordinary light.

67. EXPERIMENT.—**To convince ourselves** that ordinary sunlight contains the seven colors of the rainbow, let the spectrum produced by one prism fall upon a second prism of the same size as the first, but placed as shown in the figure annexed. The rays of light, dispersed by the first prism, have been collected by the second and *have produced white light again.*

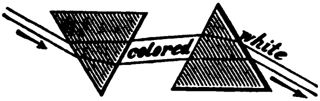

FIG. 36.

68 EXPERIMENT.—**The same** may be shown if a top, painted with the seven colors of the rainbow, is set spinning rapidly. The impressions made in the eye by these different colors are mixed together, and thus produce a mixture of the colors which is nearly white.

All this shows that *white sunlight is composed of the seven colors of the rainbow.*

69. EXPERIMENT.—**Between the crack,** or the hole in the pasteboard, and the prism insert a piece of red glass. The spectrum will then be almost entirely red, and the other colors be found wanting. Insert a piece of green glass in place of the red; the spectrum will be almost exclusively green; with blue glass it will be nearly blue, &c. It is manifest, that white light falls upon each

piece of colored glass; and that only one color at a time falls upon the prism. Thus when the red glass is inserted, only red light falls upon the prism, and consequently there can be but a spectrum of red light. The question now is, what becomes of the remaining light—or colors—which fall on the red glass? Evidently the red glass *absorbs* all the light except the red, and this it throws out. The same takes place with each of the other colored glasses; the green absorbs all the light it receives except the green light; this it throws out. The blue absorbs all the light it receives save the blue, which it throws out, &c. White glass, however, transmits nearly all the light, and absorbs very little or scarcely any.

70. EXPERIMENT.—**If a sheet** of red colored paper be held facing the sun, and a sheet of white paper before it, so as to form an oblique angle with it, the portion of the white paper which is near the red, will appear red. In this case *red rays are diffused from the red body* and fall upon the white. But the red paper receives white light from the sun, hence it must have *absorbed* all of the white light save the red; this it throws out.

*Familiar Facts.*—**Objects** near a blue curtain often have a bluish hue. The curtain receives white light, and absorbs it all except the blue, which it reflects. Objects near the foliage of

trees and bushes often have a greenish hue, because green leaves absorb all the light that falls upon them save the green; this they diffuse in all directions, and thus send green light to the objects near by.

*A body is colored when it reflects only a portion of white light. A body is white when it reflects all the white light; and a body is black when it reflects (almost) no light, that is, when it absorbs all the light.*

---

*Questions.*—What causes a piece of red cloth to appear red? It sends only red rays to the eye, the other rays it absorbs. What causes a sheet of white paper to appear white? It absorbs no light, but rejects nearly all of it. Some of this rejected or reflected light enters the eye and thus produces the sensation of white in us.

What causes a black coat to be black? It absorbs nearly all the light, consequently it sends scarcely any to the eye. The eye receives just enough light from it to become aware of its presence, but not sufficient to perceive any color.

Why is every thing black in a dark night? Because, when there is no light, objects receive none, and, therefore, they can not send any to the eye. But if no light enters the eye, we see nothing (Lesson XXXIII).

*Color is not a quality inherent in bodies.*

*Application.*—The application of colors is so manifold, that it is impossible to mention each. They serve to enliven the scenery around us, to improve our own appearance, to indicate joy or mourning. We imitate the thousand delicate hues and tinges of the colors in nature in our paintings, artificial flowers, and in many different contrivances. Colors also serve as signals to be seen from afar; hence their use in light-houses, on railroads (colored lights), and with the military (flags), &c., &c.

**Read** "*Color-Blindness,*" p. 242, and "*Principles of Harmony and Contrasts in Color,*" p. 244, in "Things Not Generally Known."

**Read** "*Color,*" in "The Earth and its Wonders."

## LESSON XXXVII.

### CHEMICAL ELECTRICITY.

71. **Experiment.—Take a plain glass tumbler**, and place in it a porous cup of earthenware (unglazed) in a manner such, that between the cup and the tumbler there is a finger's width of space left. Next have a small sheet of zinc cut as high as the cup. Then bend it into a cylinder wide enough to encircle the porous cup freely. This cylinder is open above and below, with a slit through its whole height. On the top, and opposite the slit, about a square inch of zinc is left higher than the rest. To this piece, one end of a copper wire about a foot long is soldered. The zinc cylinder is put into the space between the tumbler and the cup; the space is then filled with diluted sulphuric acid (a table-spoon full of the acid mixed with ten times the quantity of water). The cup is filled with strong nitric acid. In the acid place a plate of carbon, to the top of which the end of another copper wire is soldered. If no carbon plate can be had, a narrow strip of platinum may be used, and another wire soldered on it. If that, too, can not be obtained, fill the cup with crushed coke.[1] Thus prepared, the cup is

1. The filling with coke must be done in the following manner: Coke is pulverized in a mortar, then a small quantity is first put in the cup

placed inside the zinc cylinder; the diluted acid, of course, surrounding it. Such an apparatus is called a *cell* or *element;* if two or more *cells* are connected with each other, the apparatus is called a *battery.*

The free end of the wires must be scraped clean with a file or knife. If, then, they are brought quite near to each other, a small, bright spark is produced. If the tongue is held between the two ends, a thrilling sensation is felt.

In the first place, *the diluted acid acts upon the zinc;* this action may be seen by the minute bubbles rising from the zinc; it may also be heard. They are bubbles of a gas called hydrogen. In the second place, we have *carbon*, or *platinum*, *in contact with nitric acid;* the action which takes place here is invisible. Thirdly, *the two liquids penetrate the porous cup*, *and*, *therefore*, *meet with each other.* This action is invisible also.

*The mutual contact of two different metals* (*or of zinc and carbon*), *each placed in a certain liquid*, *produces Chemical Electricity.*

This electricity is also called "Galvanic Elec-

and a little nitric acid mixed with it, so that the powder may be soaked with acid. This is repeated several times, until the cup is nearly filled with saturated coke. On top of the coke a lump of coke is placed, around which a copper wire is wound several times, so that about a foot length of wire remains free. That the coke lump may stand firmly, surround the lower part of it by coke powder.

tricity," because it was discovered by Galvani, an Italian physician, toward the end of the last century.

The electric spark is seen only when the free ends of the wires are brought together. The zinc is in contact with the diluted acid; electricity passes from the zinc to the acids, and thence to the carbon, and from the carbon, electricity, that is the invisible *electric current*, passes along the copper wire, returns to the zinc, then to the diluted acid again, and so forth, in the same manner as above, forming an *uninterrupted current of Electricity*. If the metals (wires) are not very near to each other, no spark is seen, and the current is interrupted. If the end of one of the wires be attached to a pair of scissors, the spark will be seen at the point of the scissors on bringing it very near to the other wire. Nor would it make any difference if the wires had greater length.

(r

# LESSON XXXVIII.

## THE ELECTRO-MAGNETIC TELEGRAPH.

Next to the steam-engine the telegraph forms the wonder of our age. Its eminent usefulness and, more yet, the incredible rapidity with which it communicates messages from one place to an other, is something so new, so extraordinary, that we are tempted to believe there is nothing which the human mind is not capable of penetrating.

The fire-signals of the ancients were no longer sufficient for the increasing demands of civilization. Toward the end of the last century, so-called "optical" telegraphs, consisting of high poles erected upon high buildings or hills were used in France. By means of moveable arms attached to them, signs could be made which in clear weather were visible at great distances. But when, in 1820, it had been discovered by Oerstedt, a Danish professor, that the electric current running along a wire, exerted a certain influence upon iron, it was at once proposed to apply that influence to the telegraph.

The first electric wire by which messages were sent, was put up by Steinheil, between his place of residence in Munich and the astronomical observatory near that city. England soon fol-

lowed the example; so did America. As is always the case with new inventions, a great many improvements were made in rapid succession. It was an American, Morse, who, by a very simple but ingenious improvement, brought the telegraph to its present degree of perfection.

The principle of Morse's telegraph may be illustrated easily by the following experiment:

72. Experiment.—**A cylindrical rod** of soft iron is bent into the shape of a horse-shoe. The rod may be ½ inch in diameter and 10 inches long. Its two ends must be filed smooth; the whole is then covered with clay and placed in a coal fire. There it is left for a time and allowed to cool gradually, until the fire has gone out. After this the clay is removed, and the two ends filed smooth again. Then take a coil of copper wire of about $\frac{1}{12}$ of an inch diameter, heat it red-hot and cool it in water. Silk ribbon is then wound around it (old silk rags sewed together and cut into strips, will serve the purpose very well), in a manner such that the ribbon, about ½ inch in width, shall completely envelop it. The wire thus covered, is wrapped round the iron in close windings. (See Fig. 37.) When beginning to wrap, leave about two feet of wire free, wind then closely near to the bend;

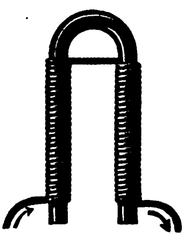

FIG. 37.

leave the bend uncovered, and stretch the wire across to the other arm. Then proceed downward to the other end, and leave the last two feet of the wire again free. Both ends of the wire are to be scraped clean, and afterward connected with the wires of the galvanic element, so that the wire starting from the carbon (or platinum) be connected with one of the wires of the horse-shoe; and the wire of the zinc cylinder, with the other wire of the same.[1]

If now a piece of soft iron, smooth on one side, or a nail, be held at a small distance from the ends of the bent rod, it will be attracted by them, and adhere. *The electricity flowing around the iron rod, has rendered the rod magnetic; its ends are now magnetic poles.* (See Lesson III.)

The galvanic current now travels from the carbon along the wire, passes through the place where the wires are fastened together, and enters the wire leading to the horse-shoe. Then it runs through all the windings of the two coils, and, in doing so, constantly flows around the iron rod. Leaving the iron rod at the other end, it passes along the copper wire, enters the (zinc) wire where the two wires are connected with each other, and, finally, arrives again at the zinc, whence it starts again to make the same travel anew.

1. The connection may be effected either by holding the two respective wire-ends firmly together with both hands, or by twisting them closely together.

Disconnect one of the wires, either by withdrawing one hand, or by untwisting the wire ends; if the iron rod is of the right kind, the piece of soft iron attached will drop instantly. If held up against the poles again, it will not be attracted so long as the wires remain disconnected. The iron rod shows no trace of magnetism. Evidently it was magnetic only as long as the electric current flowed around it.[1]

*Iron becomes magnetic when an electric current passes around it in many windings. When the current is interrupted, it ceases to be magnetic.*

Such an iron rod has usually the shape of a horse-shoe, or hair-pin, and is called an Electro-Magnet. The piece of soft iron applied to its poles is called the Keeper.

## Principles of the Electric Telegraph.

I. According to Lesson III, magnets have the power of attracting iron; by means of alternately closing and breaking the electric current, the electro-magnet renders a piece of soft iron *alternately magnetic* and *unmagnetic.*

II. The length of the wires connecting the galvanic battery with the electro-magnet is imma-

1 In most cases some electricity is left after the current has been interrupted. It lasts, however, but a short time.

terial; it may be *thousands of miles.* Thus a battery may be in the city of New York, while the electro-magnet with which it is connected is set up in St. Louis, a distance of 1200 miles of wire.

III. A person stationed at the battery, *may*, by disconnecting and connecting the wires, *break and close the current at his pleasure.*

---

**The three principles** can be demonstrated by a simple apparatus shown in Fig. 38. Two upright pieces of board, *M N*, are fastened to a table so as to admit the wooden piece, *B*, between them. The horse-shoe rod, *A*, is made an electro-magnet whenever the wires are properly connected with the galvanic element. A piece of soft iron, *d e*, on which thin paper has been pasted, is attached to a one-armed lever, *b c*,

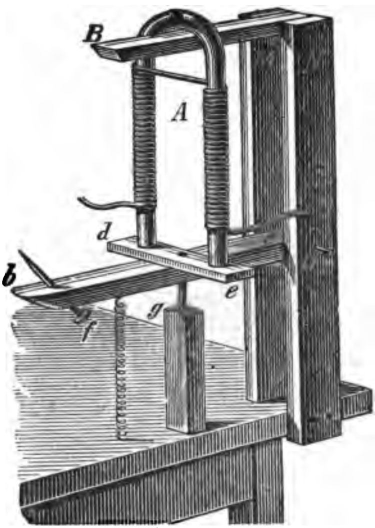

FIG. 38.

whose fulcrum is at *D*. When the electric cur-

rent passes through $A$, the poles of the Electro-magnet attract the Keeper $d\ e$; but on breaking the current by disconnecting one of the wires, the Keeper will drop. To prevent its dropping too far, there is a wooden support, $g$, which does not allow the Keeper to separate from the poles of the Electro-magnet more than perhaps 1-10 of an inch. A piece of wire previously wound around a lead-pencil, serves to draw the lever promptly downward. The paper pasted on the Keeper immediately disconnects the latter from the poles of the magnet when the current is broken. Lastly, a wooden point, $f$, writes the message upon an endless band of paper, which is unwound from a cylinder above it. This cylinder is not represented in the drawing.

When the keeper is attracted by the magnet, the point $f$ makes a mark or indentation, on the paper. But when the current is interrupted, the Keeper drops, and the point drops at the same time; consequently no mark is then made. To represent the letter *a*, for example, a sign: — ——, is impressed upon the paper; the operator at the delivery station closes the current for an instant only, this produces the small line —; then he breaks it, but immediately afterward closes it again, and keeps it closed three times as long as before. This produces the other line, ——, and now the letter *a* is on the paper of the operator

in the receiving station. To write the word table, the following signs are necessary:

—— — ——— —— - - - ——— —

*t* *a* *b* *l* *e*

Experienced operators are able to write down the messages merely from the clicking of the lever.

---

## Magnet and Electro-Magnet Compared.

Five points in common:

1. Both attract iron.
2. Each has usually the form of a horse-shoe.
3. Each has two poles.
4. In both the power resides chiefly at the ends.
5. Both are eminently useful to man: the *magnetic-needle* as a guide upon the ocean; the *electro-magnet* as a carrier of messages.

Three points of difference:

1. A magnet has no wire coil (helix) around it; an electro-magnet has.
2. A magnet always attracts iron; an electro-magnet, only when an electric current passes around it.
3. By means of a magnet, a needle may be rendered a permanent magnet; with an electro-magnet a needle is magnetic only during contact with the electro-magnet.

**Read** "*The Old Telegraphs,*" p. 69—"*The Laying of the Atlantic Cable,*" p. 193, in "Inventions and Discoveries," by Temple. Groombridge. London.

## LESSON XXXIX.

### REVIEW.

Lesson xxxii.—

1. The Sun, the Fixed Stars, Electricity, Phosphorescence, Luminous Animals, and Burning Substances, are Sources of Light.
2. Neither the plants nor most of the objects around us, are self-luminous bodies.
3. Bodies not self-luminous are visible only when they receive light from a self-luminous body, and when a portion of that light forms an impression upon our eye.
4. Light emanates from a self-luminous body in all directions, and travels in straight lines.

Lesson xxxiii.—

5. All bodies reflect light radiantly.
6. Objects with polished surface reflect light, both, radiantly and specularly.
7. All bodies appear to be in the direction whence their rays enter the eye.
8. Rays of light, on passing obliquely through substances of different density, such as glass, water, or air, deviate from their straight course; they are refracted.

Lesson xxxv.—

9. An object before a convex lens, appears magnified to the eye situated behind it.

LESSON XXXVI.—

10. White sunlight is composed of the colors of the rainbow.
11. A body is *colored* when it diffuses only a portion of the white light it receives; a body is *white* when it diffuses all the white light it receives; a body is *black* when it absorbs all the white light it receives.
12. Color is not a quality inherent in bodies.

LESSON XXXVII.—

13. The mutual contact of two different metals (or of zinc and carbon), each placed in a certain liquid, produces chemical electricity.
14. Chemical electricity travels in a circuit from its source and back again.

LESSON XXXVIII.—

15. Soft iron is magnetic, when an electric current passes around it.

    When the current is interrupted, it ceases to be magnetic.
16. The principles of the Electric Telegraph are:
    1. A piece of soft iron may be rendered alternately *magnetic* and *unmagnetic* by means of an electro-magnet.
    2. The electric current travels over *any length* of wire.
    3. A person stationed at the electric battery, may *close* and *break* the current at his pleasure.

# QUESTIONS.

(Questions preceded by a — are of a more difficult character.)

## LESSON I.—GRAVITY.

PAGE 9.—

1. Why does a stone in our hand not fall?
2. Why does it fall when drop'd?

PAGE 10.—

3. Why does a pencil roll down from the desk?
4. Whither does a stone thrown into a pond fall? and why?
5. Whither does a sign-board blown off by the storm? and why?
6. Whence does rain, snow and hailstones come? and why?
7. When does water form waterfalls?
8. Why do coals fall through the grate?
9. Why does soot, through the air?
10. To what purpose are heavy rods attached to maps and curtains?
11. To what purpose are clocks provided with weights?
12. Why is it that all bodies near the earth have a tendency to approach the earth? (Text p. 10.)
13. Give the law of gravity.

PAGE 11.—

14. Why is a string, with a weight attached, drawn straight?
15. What prevents the weight from falling?
16. What does the string indicate?
17. Define *vertical*.
18. What is a plumb-line?
19. Give the law of Direction of Force of Gravity.

PAGE 12.—

20. Why does a large stone press itself partly into the ground?

PAGE 12.—

21. Why do heavy wagons make ruts?
22. In what manner do ladies judge of silk robes?
23. Define *weight*.
24. What is a balance?
25. What are the weights?

PAGE 13.—

26. How does it come that a pound of coffee has as much weight as a pound of lead?
27. —— a pound of feathers as much as a pound of iron?
28. Of what force of Nature is the Balance an application of?
29. Clock weights?
30. Hour-glasses?

31. Why is a large drop of mercury lying upon the table never entirely round?
32. Why do wagons, unless checked, roll down hill with great rapidity?
33. Why do light bodies, such as feathers, bits of paper, &c., fall to the ground more slowly than heavy bodies, such as stones and the like?
34. Where must a rod be supported to be evenly balanced?
35. How can the weight of a body be found by means of a balanced rod?
36. Has a body the same weight on different heavenly bodies?
37. What will a pound of tea weigh on the moon?
38. What, on the sun?
39. What, in the center of the earth?
40. What, half way between center and surface?

# INDEX.

41. Would it weigh more, or less, if at a considerable distance above the surface?

42. What causes the tide-waves?

43. What, the revolution of the moon around the earth?

## LESSON II.—SPECIFIC GRAVITY.

### FLOATING AND SINKING SOLIDS.

PAGE 14.—

44. What is meant by the statement "Water is heavier than oil?"
45. How should the statement be?
46. Prove that a pound of water is as heavy as (better: has the same weight as) a pound of oil.
47. Why does a pint of mercury weigh more than a pint of water?
48. Why has a solid rubber-ball more weight than a hollow one?
49. Have all solids the same weight?
50. Have all liquids?
51. Define Specific Gravity.
52. What makes oil float on water? (Answer: The fact that oil, &c., &c.)
53. How does it come that smoke rises, while soot falls? (Quest. 9.)
54. Why does oil rise thro' water?
55. Why do balloons rise through the air?

PAGE 15.—

56. Give law about Fluids of different specific gravity.
57. Why does a piece of wood float, while a stone sinks, when thrown into water?
58. Prove that liquids have weight.
59. Will the weight of a pail of water be increased when a fish is thrown in?
60. Why does an empty flask float on water?
61. Why does it not also in air?

PAGE 15.—

62. Why does a bottle filled with water sink in water?
63. Why does it float on mercury?
64. Under what circumstances does a body float? sink?
65. Why do iron-clads float?
66. When will the body of man float?
67. Why is it difficult for bathers to walk in water chin deep? (In text.)
68. In drawing water from a well, why has the bucket more weight as it emerges from the water? (Same.)
69. Why may heavy stones be lifted in water, while on dry land they can scarcely be moved? (Same.)
70. What should persons who can not swim, do on falling in the water?

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71. Why does ice float on water?
72. Why does a full tumbler run over when a stone is thrown in, and not when a piece of sponge?
73. Why does wood saturated with water, sink?
74. Why do some bodies, floating on water, sink in it more than others; thus oak wood more than pine wood?
75. Why can persons float on water by means of life-preservers or bladders filled with air?

76. Why do we often see a sediment on the bottom of vessels containing liquids, after they have been standing for a time?
77. Why do drowned persons, after having lain under water for a time, rise to the surface?
78. Why do ships sink deeper in river water than in the ocean?
79. Why does a hen's egg float on water strongly salted, while it sinks in fresh water?
80. Why does water in a vessel rise higher on dropping into it a pound of iron than it does when a pound of lead is dropped in?
81. Why must a dog sometimes drop a heavy stone (after having fetched it from the bottom of a water) when he reaches the surface?
82. What enables fish to move up and down in the water at pleasure?

## LESSON III.—MAGNETIC ATTRACTION.

PAGE 17.—
83. Under what circumstances will a plumb-line change from the vertical direction?
84. Will it also change if its weight is a stone?
85. Mention a force which may overcome gravity.
86. Show that magnets and unmagnetic iron attract each other.
87. Give a property common to both, magnetic attraction and gravity-attraction.

PAGE 18.—
88. Where does the power of a magnet chiefly reside?
89. What is the difference between a magnet and a piece of unmagnetic iron?
90. What is the name of the ends of the magnet?
91. Where do these ends point?
92. In what position must the magnet be in that case?

PAGE 18.—
93. State the law of direction of a magnet.
94. What action is seen in two magnets whose like ends are brought together?

PAGE 19.—
95. Give law for it.
96. Whence the application of magnets?
97. Is a magnetic needle liable to deviate more on a wooden vessel than on an iron?
98. How may a magnet be made?
99. Why have magnets usually that form?
100. Describe a magnet.
101. Does the earth act like a magnet?
Give reasons for your answer.

102. What reason have the French for calling the north pole of a magnet its "South Pole," and the south pole its "North Pole?"

## LESSON IV.—ELECTRIC ATTRACTION.

PAGE 20.—
103. Whence the term "Electricity?"
104. What power may sealing-wax, sulphur and glass acquire; and on what condition?

PAGE 20.—
105. Same, regarding paper.
106. State the source of electricity.
107. What peculiar property do electric bodies manifest

PAGE 21.—

108. What phenomena may accompany electrified bodies?
109. Why the peculiar sensation felt on holding electrified paper against one's face?

PAGE 22.—

110. What becomes of electricity after it has left the sulphur, or the glass?
111. Mention two good conductors of electricity.
112. Three non-conductors.
113. Give difference between good conductors and non-conducors.

Can electricity be produced upon both classes of bodies?

PAGE 23.—

114. What phenomena take place when electrified sealing-wax is presented to a suspended pith ball?
115. When, only, do they take place?
116. Did you notice anything similar in magnets?
117. In gravity?
118. What phenomena, when electrified sealing-wax is presented to two pith balls?
119. What force is overcome in that case?
120. Was that same force ever overcome before? (Comp. question 85.)

PAGE 23.—

121. What phenomena, if first sealing-wax and then glass is presented to the single pith ball?
122. How do you explain your answer?

PAGE 24.—

123. What phenomena if first sealing-wax and then glass is presented to one of the two pith balls?
124. What phenomena if to one of the two pith balls you present sealing-wax, and at the same time, glass to the other?

PAGE 25.—

125. How many kinds of electricity? Name them.
126. Give law of electricity.
127. Explain principle and action of Lightning Rods.

---

128. On rubbing glass on flannel, do you produce only one kind of electricity, or both kinds?
129. Why does an electrified bar of sealing-wax gradually lose its electricity?
130. Why do small pith balls upon a table jump up and down, if a sheet of electrified paper be held over them.

## LESSON V.—LIGHTNING.—LIGHTNING-RODS.

PAGE 26.—

131. What was Franklin's merit regarding the explanation of lightning?
132. Give an account of Franklin's experiment.

——Why the pointed iron wire on top of his kite?

133. Could he have taken a silk string instead of a hempen one?
134. What was the purpose of the the key?

PAGE 27.—

135. What made the fibres of the string bristle up?
136. What does Franklin's experiment demonstrate?
137. What is the cause of lightning?
138. Give three paths which lightning may follow?
139. What objects are most liable to be struck? and why?

PAGE 27.—

140. Why should you not stand under a tall tree during a thunderstorm?

PAGE 28.—

141. Which is the safest place in a room during a thunderstorm?

PAGE 28.—

142. Give an account of the lightning-rod.

143. On what conditions may a lightning-rod be called good?

144. What becomes of the lightning after passing down along the rod?

## LESSON VI.—COHESION.

PAGE 29.—

145. Why is it that meat must be cut, while bread may easily be broken?

146. Why is water easily divided, while ice is not?

147. What is the name of the force which causes the parts of a solid to remain together?

148. Why is rolled iron stronger than common iron?

149. To what purpose does a knowledge of the cohesive force serve?

150. Could birds fly in water?

PAGE 30.—

151. Why would it be difficult for us to walk through molasses?

152. What must be done to break a body?

153. Why has a walking-cane lost its strength if after being broken, the parts are glued together?

PAGE 31.—

154. What is the great enemy of cohesion?

155. Why does oil form larger drops than water?

156. What are pores?

157. Why is a dry sponge smaller than a wet one?

158. What makes blotting-paper remove fresh ink?

159. Why do doors, window-frames and drawers often swell in damp weather?

160. How is it that mercury can be pressed through a leather bag?

161. What causes wooden tubs to leak in summer?

162. What may be done to prevent this?

163. Define *tenacious*. (p. 37, No. 12.)

164. Define *hard*. (Ibid.)

## LESSON VII.—ADHESION—CAP. ATTRACTION.

PAGE 32.—

165. How can two leaden bullets be made to adhere?

166. Why do not two bricks adhere in the same manner?

167. When, only, does adhesion take place?

PAGE 33.—

168. How may two rough surfaces be made to adhere?

169. Why does the hand become wet when immersed in water? (Given in text.)

170. Why does it remain dry when drawn out of mercury?

PAGE 33.—

171. What two forces are in struggle with each other when the hand is placed in water?

172. Define *adhesion*.

173. Why are two smoothly polished plates separated with great difficulty, if laid together and firmly pressed?

174. Why does fresh paint adhere to one's dress?

PAGE 35.—

175. What is a capillary tube

176. Define capillary attraction.

PAGE 35.—

177. What causes the sponge to absorb water? (Comp. 157.)
178. Why may eggs and meat be kept fresh in sand?
179. Explain the action of oil in lamp-wicks.
180. How, and why, may grease spots be removed from the floor?

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181. Why do two papers pasted together adhere firmly?
182. Why may the hand be drawn out of the water dry, if, before immersed it was cover'd with Lycopodium powder?
183. Why is a greased glass not moistened when immersed in water?
184. Why does a small drop of water on a board remain tho' the board be inverted?
185. Why does a drop of mercury fall when the board is inverted?
186. Why does a small drop of mercury on a tin plate remain when the plate is inverted?
187. Why do figures drawn with the finger upon a window-pane, become visible if we breathe on them?

## LESSON IX.—ELASTICITY.

PAGE 39.—

188. What makes an arrow, shot from a cross-bow, fly a great distance?
189. What makes steel, ivory and India-rubber resume their former position after being bent?
190. Define *elastic*.

PAGE 40.—

191. Why is the spot which an ivory ball receives upon falling on a blackened surface, larger if the ball has fallen from a considerable height, than if it has merely been pressed with the hand upon that surface?
192. Why does an India-rubber ball rebound on striking?

PAGE 41.—

193. How may the elasticity of air be shown?
194. Define *brittle*.
195. Define *malleable* and *ductile*.
196. Give examples of brittle, malleable and ductile bodies.

## LESSON X.—ELASTICITY OF AIR.

PAGE 42.—

197. Show that air, like every other body, maintains its place.

PAGE 43.—

198. Why does not water enter a bottle in the neck of which a funnel is cemented?
199. Describe the action of the pop-gun.
200. What is its principle?
201. Principle of the blow-pipe?
202. Principle of the Diving-bell?
203. What causes the air inside a Heron's Fountain to be compressed?
204. Describe the action of a Heron's Fountain.
205. Give the law on elasticity of air.
206. What is an air-chamber?
207. Describe its actio

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208. Why do fire-wheels turn?
209. Why do sky-rockets ascend?
210. Why do cannons recoil when fired off?

## LESSON XI.—PRESSURE OF AIR.

PAGE 46.—

211. Why does the water not flow from a filled inverted tumbler, with a piece of paper pressing against it?

212. Show that air presses downward.

PAGE 47.—

213. Show that air presses in all directions.

PAGE 48.—

214. Why does not vinegar flow from a barrel whose bung-hole is closed?

215. Explain the action of the "Thief."

216. Why do we not feel the pressure of air exerted upon us?

217. Why are travelers more easily fatigued on high lands than on low lands?

218. What makes us feel tired during excessive heat, or before a thunderstorm?

219. Why is it that, when a bottle filled with air in the low land is taken up on high land, the air will escape with violence when the bottle is opened?

## LESSON XII.—BAROMETER.

PAGE 49.—

220. What is a vacuum?

221. Describe the barometer.

222. What supports the column of mercury?

PAGE 50.—

223. Why does not the bulb need to be open?

224. What do force of pressure, magnetic attraction, and gravity-attraction have in common?

225. Give the amount of air-pressure.

226. What causes the mercurial column to rise?

227. What causes it to fall?

228. What is its use?

229. Whence the use of the barometer?

230. Show that the air-pressure out-doors is the same as that inside the house.

PAGE 51.—

231. Why may the barometer indicate rain?

PAGE 51.—

232. Why, fair weather?

233. Are its prophecies reliable?

234. What influence does moisture in the atmosphere exert upon the barometer?

235. To what extent may wind influence the barometer? (Remember that wind is air in motion.)

236. Why does the mercury in the barometer fall when carried up on the mountains?

237. Does atmospheric pressure increase or decrease, as we go away from the earth?

238. Supposing the moon to have a terrestrial atmosphere, how high would the mercurial column stand there?

239. How high on the sun?

240. At the center of the earth?

## LESSON XIV.—INERTIA.

PAGE 53.—

241. Show that a body at rest remains at rest until set in motion by some force.
242. Show that for a body to be set in motion, time is necessary.

PAGE 54.—

243. Show that a body once in motion remains in motion until stopped.
   Show that for the motion of a body to stop, time is necessary.
244. Define *inertia*.
245. Why is a fly-wheel an application of inertia.

---

246. Why may the loose handle of a hammer be fastened again by knocking the end of the handle against a hard object?
247. Why may a stopped-up pipe be cleaned again by forcibly knocking against one of its ends?
248. Why must good bridges have a great mass?
249. Why may a candle be shot from a great distance thro' a board?
250. Why do cannon or rifle balls make a circular hole if fired at a window-pane?

## LESSON XV.—INCLINED PLANE.

PAGE 56.—

251. What is an Inclined Plane?
252. Why does a ball on it fall?
253. Give three familiar instances of an inclined plane.

PAGE 57.—

254. Show that the steeper an inclined plane is, the greater is the velocity of a body falling on it.
255. Show that in that case the force required to ascend it is greater.
256. Show that a body increases in velocity as the space increases through which it falls.
257. Show that the greater the velocity of a body, the greater its striking force.

PAGE 58.—

258 Why does a bullet thrown with the hand inflict less harm than one fired from a gun?
259. Why may hailstones destroy standing grain?
260. What does the falling of bodies on an inclined plane show?
261. Whence the practical application of the inclined plane?
262. What is the principle of the wedge?
263. ——of the ax?
264. ——of the skid?

---

265. Why are roads leading up steep mountains made in windings?
266. What is meant by the *length* of an inclined plane?
267. What, the *height?*

## LESSON XVI.—LEVER.

PAGE 59.—

268. When is a balanced rod in a state of equilibrium?
269. Why then?
270. Why will the longer arm of a rod fall?

PAGE 59.—

271. What is to be noticed in lifting the end of the longer arm with the hand?
272. What, if the lengths of the two arms have the ratio of 1 to 2?

PAGE 59.—

273. What characterizes the end of the long arm of a lever?

PAGE 60.—

274. What have hailstones in common with a small weight at the end of the long arm?

275. Define the *lever*.

276. Give a general law about it.

277. What does the amount of power needed to lift a load by means of a lever, depend upon?

278. How may it be found?

PAGE 61.—

279. Give the three important points in a lever.

PAGE 61.—

280. What is a lever of the first class?

281. Give three examples, and explain.

282. What is a lever of the second class?

283. Give three examples, and explain.

284. To which class of levers does the oar belong? and why?

285. The wheel-barrow?

286. How may a heavy stone be lifted?

287. What is the stone then called?

288. Why are levers used only for moving loads through short distances?

## LESSON XVII.—THE PENDULUM.

PAGE 63.—

189. What is a vibration?

290. Explain the vibration of a pendulum.

291. How many forces act upon it, and what are they?

PAGE 64.—

291. Show that the vibration of the same pendulum, whether quite short or not, takes place in the same length of time.

293. Show that a short pendulum vibrates more quickly than a long one.

PAGE 65.—

294. What is the principle application of the pendulum?

295. Explain its action.

296. What is meant by winding up a clock?

PAGE 66.—

297. What is the office of the crutch?

298. Explain how it comes that *weight* in a clock causes the hands to move with uniform velocity.

299. What is the *motory* force of clocks?

300. What the *regulating* force?

---

301. Would a pendulum placed high up above the earth's surface, vibrate more quickly or more slowly than on earth?

302. How on the moon?

303. How on the sun?

304. Midway between the earth's surface and center?

305. At the center of the earth?

## LESSON XVIII.--COMMUNICATING VESSELS--HYDRAULIC PRESS.

PAGE 67.—

306. Show that the surface of quiet water is always level.

307. How does water stand in a tea-pot?

PAGE 68.—

308. Show that your statement must be true.

PAGE 68.—

309. Explain fountains.

310. What causes fountain-jets to be shorter than they ought to be?

311. How does it come that our water-pipes can lead water to the upper part of houses, contrary to gravity?

PAGE 68.—

312. Define *Communicating Vessels.*

313. Why may water-pipes under ground be said to be communicating tubes? (Text.)

314. Give law about pressure of liquids.

PAGE 70.—

315. Demonstrate it.

316. Give name and date of its application.

PAGE 70.—

317. Explain the action of the hydraulic press.

## LESSON XIX.—BREATHING—BELLOWS.

PAGE 71.—

318. Why can we, with a tube, suck up water with the mouth?

319. Explain the process of Inhalation.

320. That of Exhalation.

321. What is meant by *breathing?*

322. What is a vacuum?

323. What takes place when air has access to a vacuum?

PAGE 72.—

324. Explain the action of the bellows.

325. What is a valve?

PAGE 72.—

326. Compare the action of the bellows with the action of breathing.

327. Explain the act of smoking.

328. That of drinking.

329. Could we breathe in a vacu'm? Give reasons for your answer.

---

330. Would the bellows work in a vacuum? Give reasons.

331. Would the bellows work in water?

## LESSON XX.—COMMON PUMP.

PAGE 74.—

332. Explain the action of the syringe.

333. What causes the water to rise in it?

334. Would it rise if water and syringe, both, were in a vacuum?

335. What are the principal parts of a common pump?

PAGE 75.—

336. Where is the piston when the handle is drawn out farthest?

PAGE 76.—

337. When is the piston at its highest?

338. In that case, what is below the piston?

339. When the piston commences rising, which of the two valves is opened?

340. Why?

341. When the piston is at its highest, which valve is closed?

PAGE 76.—

342. What is meant by rarified air?

343. Why does the water in the suction-pipe rise?

344. What is the position of the valves when the piston is being lowered?

345. What do you pump out first?

346. What causes the water to flow out through the spout?

347. What causes the lower valve to close?

348. What, the higher?

349. Give the principle of the common pump.

350. What is a pump?

351. To what purpose is the lower valve?

352. The upper?

---

353. Is there any similarity between the common pump and the bellows?

354. Explain your statement.

355. Since the one serves to pump out water, and the other to pump out air, why has the latter but one valve?

356. Comparing the common pump with the barometer, give four points which they have in common.

357. Eight points of difference.

## LESSON XXI.—FORCING PUMP—FIRE-ENGINE.

PAGE 77.—

358. How high (theoretically speaking) may water be lifted with a common pump?

359. Give reason.

360. To elevate water to a greater height, what must be used?

PAGE 78.—

361. Give three points in which it differs from the common pump.

362. What are the principal parts of the forcing pump?

363. Where is the piston when the handle is at its lowest? ——When at its highest?

364. When the piston is at its highest what is the position of the valves?

365. When does the lower valve close? and why?

366. When is the upper valve opened?

367. Why does it close? and when?

368. Are both valves ever open at the same time? ——Closed at the same time?

369. Why not?

370. When the piston rises, why does which valve open?

PAGE 78.—

371. When the piston is at its lowest which valve is open?

372. Why does not the water flow back from the tube?

373. Explain the action of the forcing pump.

374. Why is it that, by means of this pump, water may be raised higher than by the other?

PAGE 79.—

375. Give the parts of the Fire-Engine.

376. Why does it not have common pumps?

377. Explain its action.

PAGE 80.—

378. What causes the flow?

379. What makes the flow continuous?

380. Give the difference between a Heron's fountain and an air-chamber?

381. Which of the two would work better in a vacuum?

382. How long will either of the two "run"?

## LESSON XXIII.—SOUND.

PAGES 85 AND 119.—

383. What causes sound?

384. What is sound?

385. What makes us hear the crack of a whip?

386. Would we hear it if there were no air?

387. Show that sound is the effect of a *vibrating* motion.

PAGES 86 AND 120.—

388. What are sound-waves?

PAGES 86 AND 120.—

389. Do we hear all sound-waves?

390. Give velocity of sound.

391. What causes the noise when paper is torn? (Text.)

392. When wood is broken?

393. When a whip is cracked?

394. Why do we not hear the alarm of a clock in an exhausted receiver (in a vacuum)?

395. Why is music heard more distinctly when near than at a great distance?
396. Why do some bodies give a louder sound than others? (Because they have a different degree of elasticity.)
397. Why is the ax of a wood-chopper, at a distance, seen to fall before the blow is heard?
398. Why may distant cannon-thunder, be heard better by putting the ear on the ground?
399. Why do deaf persons not hear?
400. Why are the bells of a neighboring place heard ringing at times, and not at other times?
401. Why is it so quiet on the mountains?
402. Why need we not speak so loud on a calm lake as on land?

## LESSON XXIV.—EVAPORATION, FOG, CLOUDS, RAIN, SNOW, HAIL, &c., &c.

PAGE 88.—
403. Define *evaporate*.
404. When does evaporation take place?
405. What change does it effect?
406. Why is the breath visible in winter?
407. Is all aqueous vapor visible?
PAGE 89.—
408. When is it visible?
409. What name has it then?
410. Under what circumstances does it become visible higher up in the atmosphere?
411. What name has it then?
412. Why do clouds stay in the air?
413. Why do soap-bubbles?
414. Why is it that the higher up the clouds, the greater the rain-drops?
415. What is rain?
PAGE 90.—
416. What is snow?
417. What is hail (probably)?
418. Whence the drops on the outside of a tumbler with cold water, in summer?
419. Why do iron safes "sweat"?
420. Whence the moisture on a window-pane when a person breathes against it?
PAGE 90.—
421. When is aqueous vapor condensed?
422. What is meant by *condense?*
PAGE 91.—
423. What is dew?
424. Why is there no dew in cloudy nights?
425. Why none sometimes, although the sky is serene?
426. What is frost?
427. Why do we not have frost in summer?
428. Why does it rain in mountainous countries more than on low land?
429. Has the direction of the water-sheds anything to do with the quantity of rain?
430. When does it rain more, in daytime or at night?
431. Give your reasons.
432. Why does it not rain every cold night?
433. Is snow useful? Why?
434. Upon what does the solid state of water, its liquid state and its gaseous state depend?
435. Will it do to compare the atmosphere to a boiler?
436. Give your reasons.

## LESSON XXV.—HEAT—CONDUCTION OF HEAT.

PAGE 92.—

437. Whence the sparks which we see when flint and steel are struck together?

438. When a horse is galloping?

439. What effect is produced by rubbing a copper coin on the floor?

440. Why does not a match ignite by being rubbed against glass?

441. Why does it ignite on a brick?

442. Why has he his hands blistered who lets himself down along a rope?

443. Why does a saw feel warm after use?

PAGE 93.—

444. How is heat produced?

445. What may motion be converted into? (Were you to ask "Into what may motion be converted?" the pupil would be inclined to answer merely a word or two.)

446. Why do the hands get warm on holding them to a heated stove?

447. What sensation is felt on keeping the end of a wire in a flame? Why?

448. What is conduction of heat?

449. Why is it that that wire (Question 447) may be held longer, if the end in the hand is enveloped in paper?

PAGE 94.—

450. Why have teapots and soldering-irons usually wooden handles? (Text.)

451. What class of bodies are good conductors of heat?

452. What is a good conductor of heat?

453. What is a non-conductor (or bad conductor) of heat?

454. Mention six non-conductors of heat?

PAGE 94.—

455. When a wire and a piece of paper that have been lying on a heated stove, are touched, the wire feels the warmer. Why?

456. Why do iron stoves heat well?

457. Why may ice be kept as well in a feather bed as in an ice-chest?

458. Why do mittens keep the hands warmer than gloves with fingers?

459. Why does iron "feel cold" in winter and "warm" in summer?

460. Why are steam-chests and steam-cylinders often covered with wood?

461. Why are the walls of safes often filled with fine ashes?

462. Why do wide garments keep us warmer than tight ones?

463. Why are frame houses warmer than stone ones?

PAGE 95.—

464. Whence the use of good conductors of heat?

465. Why are metallic vessels used for boiling water and other liquids?

466. Whence the use of bad conductors of heat?

467. Give their effect upon warm and cold bodies?

468. How should a tumbler be heated? Why?

469. Why is less heat given out by a stove when its inner surface is covered with soot?

470. What advantage in a long stove pipe?

471. Why is a glowing coal rapidly extinguished if placed on iron?

472. Why do double windows keep the room warm?

473. Why does cold wind chill us all through?
474. Why does fruit ripen quicker against a dark wall than when isolated?
475. What advantage in air being a bad conductor?
476. Does fanning us make the air around us cool?
477. Give reason for your statement?
478. Why does drawing the curtains down make a room warmer?
479. Why does snow protect the ground from freezing?

## LESSON XXVI.—DRAUGHT.

PAGE 96.—
480. Why will paper strips held over a heated stove, move upward?
481. Why will they rise if let go?
482. What is the universal effect of heat upon bodies?
483. Why does heated air rise?
484. Explain the revolving of a spiral paper owing to heat.
485. Prove that the air is warmer near the ceiling.
486. Why do balloons, smoke and steam rise? (Text.)

PAGE 97.—
487. When is a flame, held in the upper opening of a room, blown from the room?
488. How about a flame held in the lower opening?
489. Give reasons for your statements.

PAGE 97.—
490. What is draught?
491. What is the cause of draught?
492. Why is a lamp extinguished if the draught is stopped below?
493. Why, if its chimney is closed above?
494. Compare this with Experiment 26, p. 43.
495. Show that heated air rises, and that colder flows toward the source of heat.
596. What is the cause of winds

497. How long does wind last?
498. What is ventilation?
499. Is it sufficient for the ventilation of a room to simply admit fresh air?
500. Prove your statement by a previous experiment.

## LESSON XXVII.—EXPANSION BY HEAT—THERMOMETER.

PAGE 99.—
501. Why does boiling water often run over?
502. Why does a cold tumbler crack if placed on a heated surface?
503. How may the cracking be prevented?
504. What is the effect of heat upon air?
505. Why are rails placed on the track with space between?
506. How are tires placed on wheels?
507. Why does pop-corn pop?

PAGE 100.—
508. Give the law of expansion and contraction of bodies.
509. Give the parts of the thermometer.
510. Why the vacuum?
511. Why could not the glass tube be open above?
512. Can you heat the vacuum? and what will be the effect upon the mercury?
513. Why does the mercury expand from heat?
514. Why does the mercury rise? ——Why does it fall?

PAGE 101

515. How are thermometers made?
516. How are the freezing and boiling points obtained?
517. What advantage in dividing the space between those two points into degrees?

PAGE 100.—

518. Why are the plates of metallic roofing not nailed together?
519. When, and why, will hot water crack a cold tumbler?
520. What advantage in thermometers?

## LESSON XXVIII.—THERMOMETER COMPARED WITH BAROMETER.

PAGE 102.—

521. How is the blood-heat point of the thermometer obtained?
522. How is it marked?
523. How did Fahrenheit divide the space between the freezing and boiling points?
524. Where did he *not* commence?
525. Where did he commence?

PAGE 103.—

526. How did Reaumur divide that space?
527. How, Celsius?
528. What are the equivalents of 80° R?
529. What of 50° C?
530. What of 77° F?
531. What of 32° F?
532. What of 17 7-9° C?
533. What of 40° R?

PAGE 103.—

534. What is the healthiest temperature of a room?
535. Where should thermometers be placed?
536. If in New York the mercury stands 85, how would it stand in Paris (according to C.°)? (Text.)
537. How in Berlin (R.°)? (Text.)
538. According to those scales, what numbers would indicate the blood-heat point? (Text.)
539. Indicate the point of healthiest temperature in C. and R. degrees. (Text.)

PAGE 104.—

540. Give four points which the thermometer and barometer have in common.
541. Give four points they differ in.

## LESSON XXIX.—ATMOSPHERIC STEAM-ENGINE.

PAGE 105.—

542. How is a sewing-machine made to work?
543. What is rectilinear motion?
544. Circular motion?
545. Give two instances of each?
546. Who was Papin, and why is he celebrated?

PAGE 106.—

547. Mention five diff. kinds of work done by the steam-engine.

PAGE 107.—

548. Describe Papin's apparatus.
549. Describe the experiment with the same.
550. What causes the piston to rise?

PAGE 105.—

551. What to sink?

PAGE 108.—

552. What is meant by an atmospheric steam-engine?
553. Describe Savery's apparatus.
554. Compare it with Papin's.
555. Give Newcomen's improvements on Papin's apparatus.

PAGE 111.—

556. Explain Newcomen's atmospheric steam-engine.
557. What causes the piston in it to rise? Explain.
558. What causes it to sink? Explain.

PAGE 111.—

559. State the principal points of Papin's engine. (Text.)

560. Of Savery's. (Text.)

561. Of Newcomen's. (Text.)

PAGE 111.—

562. Compare Savery's apparatus with Newcomen's engine.

563. Compare Papin's with Newcomen's.

## LESSON XXX.—STEAM-ENGINE.

PAGE 112.—

564. Who was Watt?

565. Whence his familiarity with the defects of Newcomen's engine?

566. What was its principal defect?

567. What was the cause of this defect?

PAGE 113.—

568. How great a loss was caused thereby?

569. What question arose?

570. What was Watt's first im provement?

571. Explain.

572. What did Watt's next improvement consist in?

573. What defect did it overcome?

574. What caused now the piston to rise and sink?

PAGE 114.—

575. Did henceforth the steam merely serve to produce a vacuum?

576. Why was Newcomen's machine a single-acting engine?

577. Why was it used only for pumping water?

578. What constitutes a double-acting steam-engine?

PAGE 115.—

579. When did Watt die?

580. What is meant by steam of low pressure? of high pressure?

581. What are high and low pressure engines?

582. What is the use of the sliding valve?

PAGE 116.—

583. Explain action of high-pressure engine.

## LESSON XXXII.—LIGHT—ITS SOURCES—DIRECTION.

PAGE 122.—

584. What are our sources of light?

585. Mention six self-luminous bodies.

586. What is a self-luminous body? (One which makes its own light.)

PAGE 123.—

587. Are the planets self-luminous? ——Are they luminous?

588. What, then, is the difference between *luminous* and *self-luminous?*

PAGE 123.—

589. When, only, are bodies not self-luminous, visible?

590. Show that light emanates from self-luminous bodies in all directions.

PAGE 124.—

591. Show that it travels in straight lines.

592. Why have opera-glasses straight tubes?

## LESSON XXXIII.--RADIANT AND SPECULAR REFLECTION.

PAGE 125.—

593. What makes our rooms light in the daytime?

594. How do all objects reflect light?

595. What enables us to see a pencil?

596. A looking-glass?

PAGE 126.—

597. What is radiant reflection of light?

598. Show that there are objects which reflect light also in *certain directions.*

PAGE 126.—

599. What is this kind of reflection called?

PAGE 127.—

600. What class of objects reflect light, both, radiantly and specularly?

PAGE 127.—

601. Compare light reflected radiantly with light reflected specularly by

(*a.*) Giving four points in common.

(*b.*) Three points of difference.

## LESSON XXXIV.—VISIBLE DIRECTION—REFRACTION.

PAGE 128.—

602. Whither does a person hit with a stone, look?

603. Show that a boy looking at a steeple does somet'ng simil'r.

PAGE 129.—

604. On page 128 the two images have opposite directions; why does the person, nevertheless, see the object in only one direction?

605. Give general statement of the case. (All bodies appear to be situated &c., &c.)

PAGE 129.—

606. Why do oars, when immersed obliquely, appear bent?

PAGE 130.—

607. Why does the eye see the oar *bent?*

608. When is a coin on the bottom of a filled tumbler not seen in its true place and direction?

PAGE 131.—

609. Why do clear waters appear more shallow than they are?

610. What is refraction of light?

## LESSON XXXV.—PRISMS—LENSES.

PAGE 132.—

611. Show the passage of rays (of an arrow) through a prism with edge upward

PAGE 133.—

612. With the edge downward.

613. What is a prism?

614. Show the path of rays of an arrow through two prisms with their bases adjacent (as on page 133).

615. Why the use of a curved glass in place of the prisms?

PAGE 134.—

616. What two names are given to this?

PAGE 134.—

617. What is the Focus?

618. Why the term Burning-glass?

619. What effect has such a lens upon objects?

620. Is your answer true in every sense of the word?

PAGE 135.—

621. Give the general statement true of such a lens.

622. Does a telescope really magnify distant objects?

623. Upon what, then, is its use based?

## LESSON XXXVI.—COLOR.

PAGE 136.—

624. What is dispersion of light?

625. How can it be shown?

626. What effect has it upon white light?

627. Give the principal colors of the rainbow.

PAGE 136.—

628. What is the whole series of colors called?

PAGE 137.—

629. How can you prove that ordinary sunlight contains these colors?

PAGE 137.—
630. Is color a substance?
PAGE 138.—
631. Why does white glass look white?
632. Why does blue glass look blue?
633. Why do objects near a blue curtain have a blueish tinge?
PAGE 139.—
634. When is a body said to be colored?
635. When white?

PAGE 139.—
636. When black?
637. What causes a piece of red cloth to appear red? (Text.)
638. What, a sheet of paper to appear white? (Text.)
639. A black coat to appear black? (Text.)
640. Why is everything black on a dark night? (Text.)
641. Is color a quality inherent in bodies?
642. Is it a property of a body?

## LESSON XXXVII.—CHEMICAL ELECTRICITY.

PAGE 141.—
643. What constitutes a galvanic element, or cell?
644. What is a galvanic battery?
645. How is a coke-cell prepared?
646. Why must the cup used be unglazed?
(The two liquids pass each other through its pores.)
647. Why must the wire ends be entirely clean!
(The electric current does not leap over.)

PAGE 141.—
648. Whence the thrilling sensation if the current passes through the tongue?
PAGE 142.—
649. Explain the action of such a galvanic cell.
650. How is chemical or galvanic electricity produced?
651. Whence the name *galvanic?*
652. Explain the uninterrupted current of electricity
653. Is the length of the wires of importance?

## LESSON XXXVIII.—THE ELECTRO-MAGNETIC TELEGRAPH.

PAGE 144.—
654. What is next to the steam-engine the wonder of our age, and why?
655. Who discovered the effect of the galvanic current upon iron?
656. Who put up the first telegr'ph?
PAGE 145.—
657. Who perfected the telegraph?
658. How may the principle of Morse's telegraph be illustrated?
PAGE 146.—
659. What renders the horse-shoe rod magnetic?
660. Describe the path of the electric current of the cell, when passing around the rod.

PAGE 147.—
661. What effect has the interruption of the current upon the rod?
662. What is an Electro-Magnet
663. What is the keeper?
PAGE 148.
664. What are the principles of the electric telegraph?
665. Describe the apparatus by which they may be demonstrated.
666. Compare the Magnet with the Electro-Magnet, giving
(*a.*) Five points in common.
(*b.*) Three points of difference.

# APPENDIX.

## I.—REMARKS.

LESSON III.—To preserve their magnetism, the poles of magnets should constantly be kept in contact with iron.

LESSON IV.—Bar-sulphur, or a solid glass rod, is often preferred to a lamp-chimney. The surfaces to be electrified should be dry and clean.

LESSON V.—May be used as a reading lesson, or as one in which the unfinished part of any previous lesson can be brought up.

LESSON VII.—Time is gained if the bullets are flattened with a hammer; then scrape one of the flattened surfaces of each with a knife; press the two surfaces together by a few strokes of a hammer.

The glass plates, and tubes, must be free from grease.

The pores of a body may be compared to the open ends of capillary tubes; the capillary tubes may be compared to glass tubes of very fine bor

LESSON IX.—Instead of an ivory ball, which is expensive, a large marble gives the same result. The round spot may be shown also on the slab.

LESSON X.—A piece of India-rubber tubing around the tube of the funnel will do as well as sealing-wax, or any other cement. Any kind of tube, about ¼ inch in diameter and about 3 feet long, may serve as a blow-pipe.

LESSON XI.—A tumbler with a brim curved outward is best.

LESSON XVI.—A square wooden beam about 20 inches long for a lever, with the sharp edge of a ruler, paper knife or knife-blade as a fulcrum. The fulcrum must be firmly fixed.

LESSON XVIII.—The bees-wax must be put on very thin, or else the water cannot force its way through. Draw Fig. 17 on the board. The small triangular valve, when lowered, is just large enough to close the right hand side of the short horizontal tube.

LESSONS XX AND XXI.—Draw the Fig. on the board.

LESSON XXV.—Copper being a better conductor than iron, copper wire is preferable.

LESSONS XXIX AND XXX.—Draw the Fig. on the board.

LESSON XXXV—EXPERIMENT 65.—Draw an arrow on the board, place the prism in proper position, and sufficiently elevated for each scholar to see the arrow through the prism. As this requires but a few seconds, it may be found convenient to let the class slowly file past the prism.

## II.—GLASS AND CORK WORKING.

The following is taken nearly literally from Vernon Harcourt's excellent work, "Exercises in Practical Chemistry, Clarendon Press, Oxford:"

1. To Cut a Glass Tube.—Take glass-tubing about ⅜-inch external diameter ("hard glass" is preferable). For a Hero's fountain (Lesson X, Experiment 27, and also frontispiece), it should reach from within half an inch of the bottom of the flask to about eight inches above the cork. As mercantile tubing is much longer, a piece of that length should be cut off. To do this, lay the tube on a table, hold it between the thumb and forefinger of the left hand, placed close to where it is to be cut. Take a triangular file, press your left thumb and forefinger firmly against the tube, put the edge of the file upon the tube so as to touch and lean against the thumb, which will thus prevent the file from slipping over the glass, and make a notch on the glass by a few short, energetic strokes in a forward direction. While in the act of cutting, do not bear down too heavily with the left hand; rather have your left thumb yield a little as the file passes forward, so that the tube may turn a little in the direction of the advancing file. To guard against injury, in case the tube should yield, put on a glove. Now take up the tube, holding it so that the thumb-nails are opposite to each other, with the notch between them, and that you tightly press the tube (where the notch is) with thumb-nail and forefinger of each hand, and with a resolute grasp break the tube (moving your hands in a direction *from* you) as you would break a stick. The edges of the new end will be sharp and rugged; to prevent their tearing the cork, pass the file lightly over them; then hold them a few seconds in the tip of an alcohol (or gas) flame.

For a Hero's fountain like the one in the frontispiece—a more convenient form than that in Lesson X—you should have a bent glass tube.

2. To Bend a Glass Tube.—If the external diameter of the tube does not exceed half an inch, a common gas flame is very suitable; but if the gas is not at hand, a spirit lamp with a large flame may be used. Light the gas, or spirit lamp; then holding the piece of tube by its extremities, bring it a little above the flame, turning it constantly around and moving it laterally so as to heat about two inches of it equally on both sides. After a few seconds lower it gradually into the flame, still constantly turning it round.

If the gas burner be used, the glass will become covered with soot when immersed in the flame; but this is of no consequence, as the heat of such a burner is never high enough to incorporate the carbon with the glass. When the heated portion becomes soft and yielding, which will take place even before it has acquired a visible red heat, withdraw it from the flame, and gently bend it to a right angle, avoiding the use of much force. When the proper bend is completed, lay the tube on a bit of glass in such a position that the heated portion does not come into contact with any cold surface, and leave it to cool slowly.

3. To Make a Glass Jet.—Take the straight tube, previously obtained; heat the tube two inches from one of its ends by holding it to

the extent of half an inch in the upper part of a flame. The thumb and forefinger of each hand should hold the glass about an inch from the heated part. The heated part will soon become soft and a little narrower. Then withdraw it from the flame, and draw the heated part out by pulling the two ends of the glass apart. But pull very gently or else the tube will be drawn out too thin; the jet should have about ⅛-inch external diameter. Gently place the whole on the table before you and allow it to cool; then make a fine notch at the middle of the drawn-out part, and break the tube there. The long part is the jet for a Hero's fountain. If the aperture is too wide, hold it for a second or two in the flame.

4. To Perforate a Cork.—It now remains to fit these tubes—the bent tube and the jet—to the bottle by means of a cork having two holes. Take a good, sound cork, about an inch in diameter, squeeze it until it becomes soft and elastic (a pair of pliers or nut-crackers will serve the purpose of a regular cork-squeezer), then take it up between the second finger and the thumb of the left hand, and place the sharpened end of the smallest cork-borer against it, one end of the cork midway between the center and the edge. Urge the cork-borer into the cork with a twisting motion, as if you were using a cork screw. Some care will be required to make the hole straight through the cork, so that it may be truly central. Of the proper direction the eye will be the best judge. And when the cork-borer has penetrated some little way, it will be advisable to turn the cork a quarter round in order that it may be seen whether the axis of the cork-borer and of the cork are still in the same straight line. If not, a slight pressure on the cork-borer in one direction or the other will set it straight. When the borer has penetrated quite through the cork, it may be withdrawn with a twitching motion, and will bring with it a cylindrical plug of cork, leaving a hole, the sides of which should be smoothed with a round file. In the same manner make the other hole midway between the center and the circumference. Take a cork-borer rather smaller than the tubing which you have; see that the holes do not run into each other, or pierce the side of the cork. The holes should next be smoothed and slightly enlarged by a rat-tail file, until the end of one of the tubes will just enter them when some little pressure is used. (If much pressure is used, the tube is not unlikely to break, and the splinters of glass may cause injury. The hole should never be so much smaller than the tube as to make it necessary to use much force in passing the latter through it. It is a good plan, also, to wrap the tube in a cloth or handkerchief while it is being inserted in the cork.) Now pass the longer of the two tubes through the cork, with moderate pressure and a twisting motion, until it projects so far as to reach, when the cork is fitted into its place, nearly to the bottom of the bottle. When this is done pass the other tube through the other hole in the cork, until it projects one or two inches on the other side.

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A.L.